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VOL. 42 NO. 386 FEBRUARY 1956

THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 12 October 1955, the Chair being taken by Dr E. B. Evans, a Vice-President of the Institute.

The General Secretary read the minutes of the previous meeting, which were confirmed and signed as a correct record. He also announced the names of members elected since the previous meeting.

The Chairman, introducing the author of the paper to be presented, said: Cost accounting is a subject on which I do not think we have previously had a paper—it is a little off the lines of what we normally regard as technical in the narrower sense, but from glancing through Mr Taylor's paper, the subject is one with obviously technical complications. Mr Taylor is very well qualified to talk to us on this subject. He has been many years in the petroleum industry, both on the accounts side of the British Petroleum Company and for a period of four or five years on the administrative side of the refineries department. Since then he has become assistant chief accountant of the British Petroleum Company, and is a member of the Institute of Cost and Works Accountants.

The following paper was then presented in summary by the author.

APPLICATION OF COST ACCOUNTING TO OIL OPERATIONS*

By C. J. TAYLOR† (Member)

SUMMARY

The essential links with the financial accounts on the one hand, and the technical data regarding operations on the other, are described with particular reference to limitations of accuracy of measurement of time and of consumption of materials. A number of different forms of cost statement are described so as to show the difference between them, each being necessitated by the different types of operations which they cover. Further variations, having regard to the level of management to which such statements are to be presented, are also discussed.

INTRODUCTION

Historical

WHILE conventional accountancy, as represented by the double-entry system of bookkeeping, can be traced back to Roman times, cost accounting as a separate branch of accounting is barely as old as the oil industry itself. One authority[1] quotes evidence of Roman traders in partnership having to adopt a double-entry bookkeeping system as a proper means of assessing the profits of their joint ventures. Some crude form of costing, however, must have been involved, as a periodic assessment of values of stocks for interim distribution of profits was customary, and could clearly only be produced by the calculation of prices. This type of calculation for long constituted the whole operation known as "costing." Literature on accountancy is generally considered as starting with a publication in Venice towards the end of the 15th century, although a treatise covering the same field was published in London in 1543. During this 16th-century period, in association with these early accountancy publications were others relating to arithmetic, referring in particular to its value in facilitating "the calculation of cost of stocks" as required to be entered in the "Books of Account." "Cost" in this particular context clearly meant no more than the multiplication of numbers by prices. An early example of an accounting document displaying the characteristics of a cost statement, *i.e.* an analysis between components of the total cost of an operation, shows the composition of the cost per week incurred some time during 1620 by a baker in the baking of 10 qr of wheat. The object of the statement was to demonstrate that the current allowance of 6*s.* 0*d.*/qr of wheat was clearly inadequate. There must be many similar early examples of an elementary form of costing, but the recognition of costing as a separate branch of accountancy, as evidenced by published literature, is relatively recent. A representative library of costing literature is unlikely to contain volumes earlier than 1900, although an early study of factory accounts was published in 1887.[2] It is interesting to note that in a series of volumes dealing with various types of cost accounts published in the early 'twenties one volume was devoted to process costs,[3] the most likely type for application to the oil industry. However, even at that time no reference to possible application to the oil industry can be found.

The Field of Cost Accounting

What cost accounting sought to do for industry generally was to demonstrate, by analysis, the manner in which the total cost of some defined field of activity was built up. The more complex the activity, the more valuable such an analysis could be, and the complexity of engineering operations drew to that industry the major effort in the development of cost

* MS received 7 September 1955.

† British Petroleum Co. Ltd.

accounting techniques. At the time of development of major expansion of the oil industry based on the U.K., cost accounting had already become the major management tool for the determination of price in engineering operations. The days of rough calculations on the back of an envelope were rapidly passing as the margin between actual costs and roughly calculated prices was being narrowed by intensive competition. In the literature of the time there is considerable pre-occupation in the careful allocation of every imaginable expense to the various types of product produced, so that the ignorance factor which had to be included in price could be reduced to the minimum to give the best chance of obtaining business. Notwithstanding this attention to detailed allocation, greatest care continued to be taken to maintain a rigid link with the financial accounts. The starting point for both financial and cost accounts was fundamentally the journal (however varied or extended in form), and whatever was entered in the journal would be brought into the costs at the time appropriate to the particular expense, even although the timing of presentation might be somewhat different in the cost statements than in financial statements, such as the balance sheet and profit and loss accounts. The link was also obscured further in that in extracting figures from the cost accounts a greater degree of rounding off was frequently practised than in statements based on the financial accounts.

COST ACCOUNTING FOR THE OIL INDUSTRY

There was perhaps, with so young a technique, less difficulty than there might have been in its application to an equally young industry. It was true that the cost accountant in the oil industry had available for his training only the various techniques concentrated on obtaining costs for price fixing, and he found himself confronted with the problem of an industry where the cost of products could not be obtained in accordance with the conventions applied in other industries. He found in his industry that in any case price fixing was very largely a matter of adjustment to fit the ruling prices of competitive materials. To show how it is not possible to arrive at the cost of petroleum products, it is perhaps desirable to enlarge on what is normally considered to be the feature of a cost of a product from other industries. The three main components of the cost of a product are regarded as materials, labour, and overheads. In regard to materials, in practically all industries it is accepted that the unit cost of a material chargeable to products being manufactured at the same time from that material will be the same, no matter in what degree a particular material is sub-divided to meet the requirement of a particular product. This common unit rate of charge for each material is acceptable, no matter how many materials are eventually put together to produce a single product or how many products are simultaneously produced from the same materials. In this respect, it will be appreciated that the oil industry presents the accountant with an insoluble problem, for the first step in producing products from the raw material—crude oil—is the subdivision of it into fractions which differ entirely from each other and from the original crude. No single unit rate of charge to each product for the cost of the raw material is therefore acceptable. In lesser degree, the same problem is presented in regard to the allocation of labour costs and overhead charges, for the first and major unit in the refinery, the crude distillation unit, requires the attention of a labour force which is little affected by the number or nature of the fractions being simultaneously produced from the unit. While in the heavy chemical industry it might be said a similar problem has to be met, the majority of processes in that industry tend to be of synthesis rather than analysis, and there is usually a limited number of products simultaneously produced, and some are susceptible to valuation on a by-product basis. The by-product basis, for obvious reasons, cannot be applied in the case of distillation of crude petroleum.

It must not be assumed, however, that cost accounting has no contribution to make to the problem of determining prices for petroleum products. There are, in a few cases, special marketing demands for relatively small quantities of products which can be produced by the further processing of a fully marketable product as the raw material. In such cases, it is not unreasonable to calculate the price to the buyer from the market price of the product as the material cost plus the labour and overhead charges incurred in the special process. In such a case, any by-products may well be of marketable quality and can be set-off against the gross cost of the raw material.

Faced with this limited use, the attention of the cost accountant in the oil industry has tended to be focused, therefore, on the development of his techniques for the purposes of control of expenditure. This control is effected through the means of prompt publication to management, at varying levels, of current rates of expenditure analysed under appropriate headings comparing either with previous year's rates or with budget estimates. The following sections describe the characteristics of cost statements which are produced with this main object in mind.

GENERAL CHARACTERISTICS OF COST STATEMENTS

The particular characteristics of a cost statement as compared with other accounting documents are, first, the extent of the analysis of the expenditure concerned, and the addition of statistical data appropriate to the operation covered by the statement. The nature of the analysis of the expenditure will be determined by the extent of the operations covered by the statement. If the statement relates to a wide field of activity the analysis will be in terms of the various functions performed in that particular field. They might correspond to the main departments constituting the

organization of the area. If the statement relates, however, to a small self-contained unit, the analysis is more likely to be under elements of cost. The use to which the statement is to be put will decide the number of elements of cost to be included; these elements are as follows:

salaries,
wages,
materials,
chemicals,
fuel,
utilities,
sundries,
overheads,
capital charges, and
cost of feedstock.

The amount of statistical data included would again depend upon the purpose for which the statement is produced, but the minimum requirement is of the total number of units which are employed to arrive at the costs per unit where these are shown against the various headings of expenditure. Other statistical data normally appear only on those cost statements which show the above elements of cost and would include such items as personnel numbers, consumption in appropriate quantities of chemicals, fuel, and utilities, with the unit cost of such items.

CHARACTERISTICS OF COST STATEMENTS FOR PARTICULAR PURPOSES

It is convenient to consider these special characteristics by reference to two main types of costs, *i.e.* terminal costs and continuous costs. While, in some cases, the distinction may be arbitrary, terminal costs apply to those operations which can be said to have a specific beginning and a specific end within a reasonably limited period of time. They cover, for example, the operations of drilling, construction, and major maintenance work. Continuous costs cover those operations where the selection of a period for costing purposes is bound to be arbitrary and not necessarily related to the natural cycle of the operation. Such operations are production in the oilfield, transportation of crude by pipelines, refining, distribution, and marketing.

TERMINAL COSTS

With minor variations to suit the particular operation, a terminal cost statement would be expected to show the following information:

Horizontally, i.e. *columnar*

(1) Analysis of expenditure under elements of cost.
(2) The value of commitments over and above the expenditure to date.
(3) The estimate of balance of commitments to be incurred.
(4) Original estimate.
(5) Expected balance over or under estimate.
(6) Notes.

Vertically

Analysis of expenditure to units or area or type of operation.

Columnar Analysis

In the case of drilling, some variation of the columns can be expected when considering individual wells, as there are considerable difficulties in the production of a useful estimate in such operations. The columns tend to be restricted, therefore, to the cumulative expenditure with the cumulative cost per foot drilled.

With regard to construction and major maintenance work, however, in normal circumstances all the above columns can be expected. It will be noted that, so far as the cost accounts are concerned, they provide only the information in column (1). It has been found, however, that for this particular kind of accounting it is extremely valuable to incorporate in the cost cards the value of orders for materials when these orders have been placed, and appropriate deductions can be made from this column when the invoices are received. This procedure acknowledges that a firm financial commitment may be incurred some time before the completion of the work on the site has allowed the appropriate accounting document to pass through the records. It is also easier for the estimator, who is in close touch with the outstanding balance of the work to be organized, to provide the information for column (3) because it relates only to commitments which have still to be arranged, but the information in this column has to be provided in order to enable the cost accountant to complete his statement. This applies also to column (6) as, the accountant having completed columns (4) and (5) from the information he now has at his disposal, he has only reached the position to know in what cases some explanation is clearly required from the engineers in charge of the work; he could not normally provide an answer in technical terms.

Vertical Analysis

Turning now to consider the extent to which vertical sub-divisions under units or areas in this type of expenditure can be regarded as reasonable, the demands for analysis may emanate from three sources, *i.e.* the estimator, the contractor (assuming that he is not necessarily the estimator), and the accountant. The estimator would clearly call for such analysis of expenditure as will match the various headings which he had in mind when preparing his estimate, which will clearly vary with the magnitude of the job, particularly if the period of construction is so lengthy that escalation of certain items of cost may have to be faced. Having regard to the fact that some degree of tolerance in the accuracy of estimates must be permitted, the estimator would probably be satisfied with a series of broad headings. The contractor, on the

other hand, who may be concerned with only part of the total scheme which has been estimated by the estimator, would look for a great deal of analysis very promptly so as to be assured that the rate of expenditure on the job is matched by the progress in the construction. Such information is also of great help to a contractor in drawing up subsequent tenders for work of a like nature. The accountant's requirements are generally of a much more limited nature, he being concerned with the possible requirements of the Inland Revenue and with the subsequent use of the capital costs in the assessment of the financial results from the operation of the various plants contained in the scheme. In present-day conditions, the construction of a new refinery on an entirely new site is the best example of this particular problem. The accountant's requirements might be met by an analysis on the following lines:

(*a*) *Process Units*

Distillation units—atmospheric and vacuum
Re-distillation units
Cracking and reforming units
Treating units
Lubricating oil processes
Fuel oil and gas system
Slops treatment unit
Process tankage
Oil lines and pumphouses
Etc.

(*b*) *Installation*

Jetties and foreshore buildings
Tankage
Main pipelines and pumphouses
Product loading facilities—road–rail
Lubricating oil blending and packaging

(*c*) *Refinery Services*

Utilities
Effluent system
Spent chemicals disposal
Drainage system
Sewerage
Roads, railways, bridges, and fences
Lighting
Fire service
Stores and workshops
Laboratory
Administrative building

It will be noted that in some groups further details would be given for each plant unit or service. The list does not show the cost of a number of operations which, having been determined and shown separately during the construction period, are subsequently dispersed by allocation over the other headings in proportion to the service rendered. It is in such service operations that it may be necessary to bring in an element of depreciation, although this is not expenditure which is reflected in the current cash book. The departure from the principle of including only current expenditure is justified only where the useful life of the equipment which is rendering the service is relatively short. In most operations coming within the scope of terminal costs the time factor is of prime importance, and such equipment as drilling rigs or civil engineering plant, *i.e.* earth-moving equipment and the like, might be worked almost to destruction during the period of the main operation. It is not unreasonable in such cases to include a generous rate of depreciation even if the equipment, at the end of the task, may be available for further work.

To effect a compromise between these varying demands is not always easy, but if the project is of reasonable magnitude the cost accountant nowadays can avail himself of a punched card system which is of such assistance in the tabulation of a mass of data in more than one way. No analysis of the data is possible by any means, however, unless it bears a variety of identifying codes to render analysis possible. It is at this point that the cost accountant becomes almost entirely dependent upon the operator in the field for the ultimate accuracy of the costing information he produces.

Irrespective of the type of cost concerned, the raw materials on which the cost accountant works are the labour time sheets, materials consumption notes, steam and power meter readings, and many other technical data, the accuracy of which is normally beyond his control. Close co-operation between the cost accountant and the management is required to see that any system of coding for costing purposes does not impose too great a burden on the operator, who alone can make the allocation at the very source. If such codes are too detailed, inaccuracies arising out of hasty allocations are bound to follow; due allowance must always be made for the limited time available to the operator for clerical work. In work of sufficient magnitude it may be useful to employ cost checkers who, on a sample basis, can check the allocations endorsed on time sheets and the like, but it is seldom a satisfactory procedure, as such checking is inevitably done some time after the event and might be thought to be an encouragement to the hard-worked operator to give less attention than he should to the allocations that he makes. However, in the major operation of constructing a refinery or other concentrated effort carried out at high speed, cost checkers may be a necessity and can be used, as there can be visible evidence to support cost allocations.

The accuracy of the accountant's output is, therefore, closely dependent on the relations he succeeds in establishing with the operating side. When considering the cost of cost accounting, while it is easy to identify the expenditure involved in the cost accountant's office, it must not be overlooked that a fraction of the time of many of the workers in the field is employed in facilitating the operation of cost accounting. These particular remarks apply not only to every variety of terminal costs but to every variety of continuous costs as well.

CONTINUOUS COSTS

The types of operation covered under this heading can be conveniently considered in two main groups:

(1) Production, Transportation by Pipeline, and Refining.
(2) Distribution and Marketing.

PRODUCTION, TRANSPORTATION BY PIPELINE, AND REFINING

Cost statements covering these operations have certain features in common, as they can be expected to contain the following information:

Columnar

(1) Expenditure during the period.
(2) Estimate for the same period.
(3) Corresponding figures for the same period of the preceding financial year.
(4) Moving annual total.
(5) Unit costs.

Vertically

Analysis of expenditure—either (i) by units or area or type of operation or (ii) by elements of cost.

Columnar Analysis

The first column, *i.e.* the period of the expenditure, is subject to considerable variation, mainly in relation to the nature of the vertical analysis. Thus, a statement covering a wide field of operation, having only a few main headings vertically, is usually intended to convey, at fairly frequent intervals, a broad picture of the current trend of expenditure. In this case, for column (1) the period selected would be the cumulative total to the end of the month under consideration, and publication would tend to be monthly. The final statement in a series would normally be the financial year. While it might be said that the financial year is quite an artificial period so far as continuous operations are concerned, it is nevertheless convenient, if only from a seasonal point of view, to build up to 12-monthly figures; it is equally convenient for the 12 months selected to coincide with the 12 months employed in the financial accounting. There are cases, however, where, owing to relatively unimportant short term variations, the system of moving annual totals is to be preferred.

In order to avoid short term fluctuations in cases where the moving annual total may be considered inappropriate, a compromise is to publish figures commencing with the first three months of the year and thereafter monthly on a cumulative basis. This is particularly valuable where a close comparison is desired with an estimate. It will be noted the emphasis is on the comparison with the estimate, although the corresponding figures for the same period of the preceding year are sometimes useful as a guide. There may indeed be a considerable change by comparison with a preceding period, but time would be wasted in pursuing this if it were clear that the sanctioned estimate had provided for the increase shown. As regards the units to be selected for the calculation of unit costs, the limitations of measurement techniques may decide the point at which the unit figures are obtained, *e.g.* so far as concerns production of crude in the field it is usually most convenient to measure this at the point at which it is passed into main storage either at the head of the pipeline system, the seaboard, or the refinery.

In the case of transportation by pipeline, it is normal to use as divisor the sum of quantities delivered from the pipeline, so that the unit cost would automatically reflect the effect of line losses by leakage, etc.

In a general summary of refining costs the crude oil throughput generally suffices as divisor for the purely refining expenditure. For the installation expenditure at a refinery the gross tonnage, *i.e.* tonnage received plus tonnage delivered, provides a useful unit cost per ton. For cost statements covering individual processes or operations the tonnage put into the particular unit or units under consideration is normally the most useful divisor. For statements covering the ancillary services such as steam, power, etc., the net output available for distribution to users is to be preferred.

The field of distribution and marketing contains a number of different types of expenditure, and the grouping of the expenditure will determine the divisor, *e.g.* a broad summary of the various types of expenditure incurred throughout an extensive area would have as divisor the total sales in the area, but the individual items, such as installation costs or transportation costs, would necessarily have divisors related to the quantities actually handled, *i.e.* the installation throughput and either the volume carried or the ton mileage (or equivalent) involved.

Vertical Analysis

The degree of sub-division between units, areas, or type of operation must be formulated, as in the case of terminal costs, with due regard to the time available to the worker on the site for the maintenance of time records of the various tasks on which he may be engaged. In regard to normal operations, therefore, a unit for costing purposes would be formed to cover all expenditure taking place within a defined area which might contain more than one plant unit if such units were under single control. Where the functions of those units may be very different in nature there has, however, to be some allocation so that the cost of the particular function performed can be thrown out. There may, for example, be a common control room for a line of lubricating oil plants, but clearly the cost of each process in that line will require to be known, and an appropriate system of allocation of work common to all units will have to be found.

In the example shown of a typical cost summary in regard to production (Fig 1) it will be noted that the

headings are appropriate to Middle East conditions. Thus, to show a comprehensive total of production expenditure, not only is it necessary to detail such direct activities as the maintenance of production wells and units, gasoline recovery plants, etc., the expenses of geological services to the producing areas, of the petroleum engineering department, and of such drilling as is appropriate to producing activities, it is also necessary to show a detailed analysis of the many establishment expenses which fall on to the company's organization in the relatively isolated areas in which so often the large producing areas are found (Fig 2). Thus, there is often found within the responsibility of the field management the transportation of foodstuffs and domestic supplies from the sea port, the cash "expenditure" represented by the allowance to cover repairs, maintenance, and depreciation of the drilling plant and tools used for the work.

The pipeline transportation cost may be demonstrated in a simpler form, as some services may well be administered by either the field organization at one end or the port or refinery organization at the other.

In the case of the summary of refinery and installation expenditure (Fig 4), it has been assumed that the refinery is situated in Europe and will have attached to it rather more storage than will be needed for purely refining operations and that there will be some provision for delivery by other means than full cargo lots, *i.e.* from the small coastal tanker down to the small lubricating oil tin. It has been found convenient to

Typical Summary of Production Expenditure Period to End .....

Heading	Expenditure for the period	Estimate for the period	Over/under expenditure on estimate
Production			
Crude			
Natural gasoline . . .			
	£	£	£
(1) Direct expenditure			
(a) *Production*			
(i) Crude production, operating, and maintenance .			
(ii) Gasoline recovery plants .			
(iii) Repressuring units . .			
(iv) Production office and control instrument services			
(b) *Geological*			
(c) *Petroleum engineering* . .			
(d) *Drilling*			
(i) Development wells . .			
(ii) Work-overs . . .			
Total direct expenditure . .			
Cost per ton production . .			

Heading	Expenditure for the period	Estimate for the period	Over/under expenditure on estimate
	£	£	£
(2) General establishment and indirect charges			
(a) *Personnel charges* . .			
(b) *Stores, handling, and transport charges* . .			
(c) *Area charges* . . .			
(d) *Indirect charges* . .			
Total general establishment and indirect charges . .			
Less: applicable to non-production activities. .			
Net general establishment and indirect charges . . .			
Establishment cost per ton production			
Total crude oil production expenditure (including establishment)			
Total cost per ton, production .			

FIG 1

support of organizations concerned with sports and social services, the provision of medical and public health services, the maintenance of housing, the counterpart of all of which is not met in anything like the same degree in other fields of activity.

Although drilling expenditure has been referred to under terminal costs, as is appropriate when considering individual costs per well (Fig 3), it is often the case that the long term programme of development drilling in a number of areas can conveniently be studied on similar lines to continuous costs of other operations in the field. Such a statement would amplify the drilling section on the main summary of production expenditure. The expenditure on development wells would be analysed under the usual headings appropriate to the drilling activity, and would therefore include such items as the installation of roads to wells, installation of water services, etc. In the case of work-over operations, however, a less detailed analysis would suffice, *i.e.* the cash expenditure incurred in salaries, wages, and consumable stores and the non-

group together, separately from the other refinery operations, the following special activities:

(1) handling of tankers at the wharves in the oil port;

(2) movement of crude oil and products between the refinery and the oil port;

(3) storage of crude oil and products, and

(4) the delivery of products from the refinery, by whatever means.

There is thus left, as appropriate to the refinery proper, the operation of the process units only together with the pumphouses and auxiliary tankage required for movements between units and delivery of products to finished storage. The analysis of operating costs shown on such a statement would tend to follow the general grouping, referred to in the paragraph on Vertical Analysis (p. 36), as it is probable that such an analysis would automatically correspond with the operating organization. The trend of expenditure in these various groups can then be con-

veniently seen and quickly advised to the head of the group of plants concerned, together with supporting analysis by units. In those special cases where, owing to the nature of the study being made, a depreciation tankage, provided such pumphouse or tankage is reasonably near to the unit and is hence in the care of the same control staff as the unit. If dipping of such tankage is carried out otherwise than by the operating

Typical Summary of General Establishment and Indirect Charges Relating to Production Period to End .....

Heading	Expenditure for the period	Estimate for the period	Over/under expenditure on estimate
Production			
Crude			
Natural gasoline			
	£	£	£
Expenditure			
(a) *Personnel charges*			
Supplies and services			
Social services			
Medical			
Public health			
Motor transport (personnel requirements)			
Aerial transport			
Employees' quarters			
Workmen's compensation, etc.			
Workmen's sick and lost time			
Travelling expenses and allowances, etc.			
Training			
(b) *Stores' handling and transport charges*			
Stores' handling:			
Stores' operations			
Stock adjustments and stock revaluation			
Shipping (cargo)			
Motor transport (goods)			
(c) *Area charges*			
Roads			
Communications			
Fire prevention, guarding, etc.			
Sewage disposal			
(d) *Indirect charges*			
Office charges			
Area general charges			
Total general establishment and indirect charges			
Less: applicable to non-production activities			
Net general establishment and indirect charges			
Establishment cost per ton production			

FIG 2

charge is required to be added, the necessity for the analysis of the capital costs of the refinery in the manner shown in the section on Vertical Analysis (p. 36) becomes apparent; only in this way can "all-in" costs be calculated.

It is a common convention to include in the operating costs of a unit the costs of running the pumphouse for the despatch of its products and of the process staff, it may still be desirable to charge the cost of such dippers as a service to the plant operating cost.

While common services such as utilities, which can be conveniently allocated in proportion to measurable consumption, are not shown separately in this type of summary, expenditure of the nature of establishment and indirect charges are shown in detail for separate study even if, for consideration of an all-in

Typical Summary of Drilling Expenditure by Wells

Well no.	Area	Expenditure in previous years	Expenditure for period to	Expenditure per well to date	Cost per foot drilled	Estimate to date	Footage drilled			Remarks
							in previous years	this year	total to date	
		£	£	£	*s. d.*	£				
(1)										
(2)										
(3)										
(4)										
(5)										
(6)										
(7)										

FIG 3

Typical Statement of Refinery and Installation Expenditure Period to End .....

Heading	Expenditure for the period	Estimate for the period	Over/under expenditure on estimate	Heading	Expenditure for the period	Estimate for the period	Over/under expenditure on estimate
(1) Refinery				**(2) Installation**			
Gross throughout—tons				*Total tonnages handled*			
	£	£	£	inwards—crude oil			
				,, products			
Charges on process and intermediate oils				outwards—products			
Refinery expenditure				Total tons			
(*a*) Distillations							
Atmospheric distillation				(*a*) Jetties and dredging			
Vacuum distillation				(*b*) Pipelines and pipetracks			
(*b*) Treatments				(*c*) Storage and loading			
(*c*) Blending of additives				(*d*) Lub oil storage, handling, and despatch			
(*d*) Lub oil manufacture							
(*e*) Cracking–Reforming				Total installation expenditure			
				(3) General establishment and indirect charges			
				Personnel charges			
				Stores handling and transport charges			
				Area charges			
				Indirect charges			
Total refinery expenditure				Total establishment charges			

Summary of Refinery Costs

Actual	Estimate	Over/under

Summary of Installation Costs

Actual	Estimate	Over/under

Tonnages

(1) Refinery expenditure, cost per ton
(2) Installation expenditure, cost per ton
(3) General establishment expenditure, cost per ton
Total expenditure, cost per ton

FIG 4

cost of refining, a proportion of these charges in total only is set aside as being applicable to the installation operations. While the analysis of such refinery establishment charges will be seen to be very similar to that employed in the producing field, it will be study of the costs of individual units or small groups of units, and will be found of value for some operations in the producing field, very frequently in the refinery, and, with appropriate modifications, in distribution activities. It is also useful in demonstrating the costs

Specimen Cost Summary

Sheet no. : .....
Operation : .....
Reference no. : .....

Particulars	1955			
	Period to			
	Actual		Estimate	
		Cost per ton		Cost per ton
Operating	£	*d.*	£	*d.*
Salaries				
Wages				
Materials				
Chemicals				
Sundries				
Fuel				
Liquid				
Gas				
Maintenance				
Salaries				
Wages				
Contract payments				
Materials				
Overheads				
Main Services				
Power				
Steam				
Water—Industrial				
„ Cooling				
Compressed air				
Fuel and effluent systems				
Total				
Input—tons				

	Statistical Data			
	Unit	Quantity	C.P.U.	Quantity	C.P.U.
Chemicals			£ *s. d.*		£ *s. d.*
Main services					
Power	kW-hr				
Steam	1000 lb				
Water—industrial	1000 gal				
„ cooling	1000 gal				
Operating personnel					
Staff	Nos.				
Labour	Nos.				

FIG 5

appreciated that the extent of the expenditure, as compared with the direct cost of operating the process units and the installation, would be very much less. There is likely to be, however, by way of compensation, a somewhat higher level of wage rates and an item of local rates which will go some way to restoring the level of costs.

Statements with the vertical sub-headings under elements of cost (Fig 5) are of wide application for the of ancillary services such as the provision of steam, power, and water.

DISTRIBUTION AND MARKETING

The nature of distribution and marketing operations differs so much that it has been found convenient to adopt a rather different form of presentation. The operations have the feature of considerable repetition

Typical Distribution Cost Summary Budgetary Control Statement

Company .....

Period to .....

Nature of expenditure	Current period		Same period last year		Proportion of budget estimate	
	Amount	Unit cost	Amount	Unit cost	Amount	Unit cost
	£	s. d.	£	s. d.	£	s. d.
Installations						
Salaries and wages—admin. and clerical						
" " " operating						
Personnel and welfare						
Operating expenses						
Standing charges (incl. depreciation)						
Depots						
Salaries and wages—admin. and clerical						
" " " operating						
Personnel and welfare						
Operating expenses						
Standing charges (incl. depreciation)						
Delivery and inland transportation						
Lorries						
Craft						
Rail tank wagons—repairs, etc.						
Other delivery costs						
Package costs (incl. depreciation)						
Hired lorries						
Hired craft						
Hired rail tank wagons (excl. rail freights)						
Rail carriage						
Coastwise freight						
Selling						
Service stations						
Kerbside pumps, etc.						
Airfields						
Agents' commission, etc.						
Salesmen–Travellers total expenses						
Advertising						
Branch offices						
Personnel						
Office buildings						
Sundries						
Head office						
Personnel						
Office buildings						
Sundries						
Total						
	Tons		Tons		Tons	
Divisors						
Installation throughput						
Depot throughput						
Quantities transported						
Airfield deliveries						
Service station deliveries						
Other deliveries						
Total sales						
	No. at end of period		No. at end of period		Area establishment	
Staff and labour						
Staff						
Labour						

FIG 6

over a wide area in contrast to, particularly in the case of refining, a greater number of operations within a single area. Another feature of distribution and marketing expenditure is the higher proportion, as compared with other operations, of expenditure which is inflexible in relation to the level of activity. Where trade has a seasonal trend it is in the distribution and marketing operations that it is most strongly felt, and wide variations in unit costs may well result. As standards of unit costs for control purposes are thus more difficult to establish, the employment of an annual budget estimate is of major importance.

For the central organization it is considered desirable to have a single summary sheet which will give a picture of the total expenditure throughout the whole area of the company's activities (Fig 6). The analysis shown would be as follows:

Columnar

(1) Current period.
(2) Same period last year.
(3) Proportion of budget estimate.

Vertically

The main sub-headings correspond to the five main divisions of operations. These are:

(1) Installations.
(2) Depots.
(3) Transportation.
(4) Selling.
(5) Administration.

It is appreciated that the distinction between installations and depots may at times be arbitrary, particularly with the development of river-side or canal installations fed by large barges. Administration may be conveniently considered in two sections where there is not complete centralization, *i.e.* branch offices and head office.

Under the main sub-headings some further division of cost is desirable. For the first two and the last sub-heading some grouping of elements of cost on the following lines is suitable:

(1) Salaries and wages.
(2) Personnel, etc., expenses.
(3) Operating expenses (this would be mainly materials).
(4) Standing charges.

Transportation costs, on the other hand, would normally be most usefully analysed under the types of vehicles or craft, distinguishing also between company-owned and hired vehicles. Selling costs are best analysed to show the somewhat different functions covered by that heading as follows:

(1) Expense in relation to selling points, *i.e.* service stations, airfields, etc.
(2) Expenses in relation to salesmen, travellers, agents, etc.
(3) Advertising.

Such a broad summary would need to have a statistical section showing the quantities used for divisors and personnel statistics. While such a summary is primarily designed to cover the whole of a company's activities, it is clear that, should the total activities within a branch area involve a considerable annual expenditure, the same form with only minor adjustment should prove helpful in studying the trend of expenditure.

Each of the main headings can also be made the subject of separate cost statements which will go into a little more detail, *e.g.* full analysis between elements of cost would be shown on statements dealing respectively with installations and depots (Fig 7), service stations, or airfields. In these cases, however, it may be preferable to replace the column "Proportion of budget estimate" by a 12 months' moving average, or there is a further alternative—to restrict the period in the first column to a quarter and to put the cumulative total for the current financial year in place of the 12 months' moving average. The statistical information which is useful to apply to the expenditure varies considerably, so that no one form is appropriate to these various activities. A cost statement in relation to an installation or depot would require to show an analysis of deliveries between bulk and packed and by types of vehicle. The personnel analysis would give figures distinguishing between administration, vehicle operation, vehicle maintenance, installation operating and maintenance, and, if necessary, casual labour.

Service station costs may be submitted in a number of ways, there being many variations in the financial relations applying to such stations as they may be owned by the company or leased to a dealer under a variety of terms. It may, therefore, be convenient to study the costs of all service stations of a particular type within a given area and, in exceptional cases, to study the costs even of a single service station. No cost statement would be complete without appropriate statistics such as total deliveries by pumps, packed, etc., and some analysis of total deliveries by grades, *i.e.* benzine, derv, lubricants, etc.

The airfield cost statement would cover the costs of staff and fuelling crews and the maintenance of buildings and equipment at the airfield; it would not include the cost of transportation to the airfield. The analysis of expenditure would be largely in terms of the elements of cost, but unit costs would normally be shown only in respect of personnel and fuelling vehicles as it is only under these two headings that much opportunity arises in limitation of expenditure by reference to deliveries to aircraft.

In the case of transportation costs it may be desirable to consider them in two distinct groups. First, the "bridging" operation, which is solely concerned with the economical movement in large quantities from installation or sub-installation to depot; in this case, the normal ton–mile unit (or equivalent) is the most satisfactory divisor. Secondly, vehicles may be engaged in a limited area dispensing in relatively small quantities to the dealer. From the point of view of

vehicle efficiency alone the ton–mile unit is to be preferred, but some difficulty may be experienced in getting accurate measurement of this factor if partial drops are the feature of this particular operation. Considering the fact, however, that the driver in these cases is also a salesman, from the point of view of which are much less susceptible to the trend of trade than the other types of cost already referred to, and are correspondingly more difficult to control. While it may be useful to study a long term trend by reference to a 12 months' moving average, it is nevertheless worth considering whether it is possible to prepare a

Typical Installation/Depot Cost Statement

Period to .....

Nature of expenditure	Current period		Same period last year		12 months moving average	
	Amount	Unit cost	Amount	Unit cost	Amount	Unit cost
	£	s. d.	£	s. d.	£	s. d.
Salaries and wages—admin. and clerical						
" " " operating						
Personnel expenses and welfare						
Consumable stores (excl. maintenance)						
Repairs, maintenance, and painting						
Utilities and fuel						
Telephones, telegrams, postage						
Miscellaneous						
Rent						
Rates and taxes						
Depreciation						
Total installation expenses						
Exceptional expenditure (incl. extraordinary maintenance)						
Deliveries—bulk						
By: Lorries						
Hired lorries						
Rail						
Direct pipeline						
Vessel						
Deliveries—packed						
By: Lorries						
Hired lorries						
Rail						
Vessel						
Total throughput—bulk and packed						
	No. at end of period		No. at end of period			
Personnel analysis						
Number of employees:						
Admin. and clerical						
Drivers and mates						
Pump and vehicle mechanics						
Normal operating force (incl. foremen)						
Casual labour						
Total						
	Current period		Same period last year			
Labour force analysis						
Actual man/hr worked (excl. overtime)						
Total possible man/hr						
Percentage—actual to possible						
Man/hr on overtime						
Percentage—overtime to actual						
Total man/hr worked						
Throughput handled per man/hr worked						

FIG 7

efficiency of the operation of delivery to customers, it is probable the mileage should be disregarded entirely, and the unit of volume delivered to the customer will give a better appreciation of the value of the work being done.

A study of the total expenditure of a distributing organization would not be complete without a statement covering the head office and branch office costs, budget estimate and to endeavour to control this type of administration expenditure by this means. Analysis of such head office expenditure need not be very extensive, but should distinguish between the expenses of salaries, wages, travelling, etc., of the administrative personnel, the costs of the office buildings housing them, and, finally, the miscellaneous expenses attaching to an administrative organization

such as telephones, stationery, donations, and the like. As far as a cost unit is concerned, while it is of limited value, the total trade within the area administered by the office can be used.

PRESENTATION

The foregoing summary of a series of cost statements may be said to be appropriate for submission to the upper middle level of management. For higher levels of management a condensed form of these statements can easily be produced by extraction. Levels of management concerned with smaller fields would only require a simpler form of statement showing an analysis over elements of cost for the unit or group of units concerned. In producing such a variety of statements for study at different levels, the burden upon the cost accountancy system must be lightened by establishing varying frequencies of publication for the different types of statement and, further, varying degrees of "polish" can be used in the published document. A process plant or depot superintendent, for example, need not have a summary of cumulative costs very frequently, and when supplied to him the form might be roughly drawn, even in manuscript by extraction from the appropriate cost card. It must be borne in mind that at this level the purpose of the statement is to act as a reminder of the total financial effect of the methods employed by the plant operator or depot superintendent in carrying out his work. The upper end of management is more concerned to have a few key figures at frequent intervals so that they can keep in mind the current cost of the operations in which they are particularly interested.

This spreading of the load is also important as a means of providing time for the cost accountant to produce non-routine statements required to illustrate a particular problem which may arise. This *ad hoc* cost statement is more often concerned with estimating the probable effects of some future action, *e.g.* a change in processing arrangements to provide an alteration in quality. Such a statement will try to show, by reference to current cost levels, the changes in cost by the employment of different plants or by changing the level of operations at existing plants, and it is in the preparation of such statements that the cost accounting system relinquishes its close link with the financial accounting system. It will be appreciated that it is only because of the highly detailed analysis of the many factors building up costs which the cost accounting system contains that estimates with some likelihood of meeting performance can be prepared. It is in making use of this mass of data that the importance of appreciating the accuracy factor, even in so called actual costs, comes to light. Once that accuracy factor is understood, then the production of an estimate which may be rounded off to only a few significant figures can be more properly appreciated. One should not expect an estimate of cost running into perhaps six figures to end in anything but three noughts. The form of presentation of cost information can be expected to vary, therefore, in relation to the variety of questions which are demanded of the cost accountant. The wide variety of answers required can nevertheless be derived, either by condensation or further analysis, from the main body of statements which have been described.

VALUE OF COST STATEMENTS IN PERIODS OF CHANGING MONEY VALUES

It will have been noted that most of the cost statements described are designed to enable management to appreciate the trend of expenditure by reference to a previous period or to a budget estimate which must clearly have been calculated in a preceding period. In periods of changing money values, comparisons with the past, whether of actual or estimate, may become unexpectedly of less value by reason of, for example, a major wages award to a particular craft. In any analysis, therefore, in the costing records some care must be taken to ensure that those elements of costs which are likely to vary in very different degrees when such changes take place can be clearly isolated. It becomes a matter of careful consideration by the cost accountant as to when he must re-calculate his estimate or vary the period with which comparison has been made to allow for a change which appears to be permanent. In the changing of such estimates it is important that the impression should not be conveyed of complete acquiescence in the continuance of the revised level of costs demonstrated. The calculation of such adjustment is a very convenient time to assess whether, by some modification of operations which might involve further capital expenditure, the enhanced cost of some particular element of cost may be, in some degree, ameliorated. This brings out a feature of the system referred to earlier, *i.e.* that it should be possible to demonstrate from the actual costs achieved what financial benefit has accrued in relation to the capital expenditure which was involved in effecting the change. Such studies may well involve the extraction of costs for unorthodox periods so as to cover a cycle of operations under fair conditions. While it may be said, therefore, that when we are confronted with a long period of changing money values the normal cost comparisons might prove misleading, the cost accounting system should be able to find means of making appropriate corrections for this disturbing factor.

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DISCUSSION

W. S. Thompson: My main interest in costing as applied to oil operations is on the refining side, and there are one or two points I would like to raise with Mr Taylor.

In particular, the paper contains a definition of terminal costs—"Work which had a specific beginning and a specific end in a reasonable limited period of time." Mr Taylor has stated that extraordinary maintenance work belongs under this heading. In so far as the actual work itself is concerned, I agree with that, but I feel that some reserve should be made for this maintenance work in the continuous cost which Mr Taylor also mentioned, for the periods prior to the maintenance work being carried out. In present-day refining operations, where very expensive plants, in many cases costing millions of pounds, are kept in continuous operation for periods of twelve months or more, it is generally accepted that during the twelve months, or longer period, the plants are deteriorating very considerably, but the continuous costs have no regard to that deterioration. In my opinion it would be prudent, during the time of operation of the plant, to charge in the continuous costs, some figure based on an estimate from the engineering department, of what these maintenance costs would amount to during the shut-down period.

The second point I would like to make is on the mechanics employed by the accounting department in the preparation of costs. The paper states that punched card equipment might be justified in work required for the preparation of statements. In my opinion, the oil industry now, particularly on the refining side, should be studying the use of electronics and automation, not only on the accounting side, but also on the operating side. I can visualize that with suitable electronic machines, the necessary data concerning plant throughputs and production, which is one of the items I find which takes the longest to come through from the refining departments, and which holds up the preparation of costs, could be speeded up so much that complete costs statements should be available within days, or even hours, of the end of the continuous cost period in question. I wonder if Mr Taylor has given any thought to this branch of mechanization, as applied to cost accounting, particularly of refining operations.

There is only one doubt I have in my mind on that, and that is, if and when electronics are fully applied, I think Mr Taylor and myself will find ourselves out of work.

The third point I would like to comment on is the necessity for co-operation between operating people, that is chemists and engineers on the one hand, and the accountants on the other hand, in the preparation of costs. The fact that the accountant prepares the final statement tends, at least in some people's minds, to put the responsibility for any shortcomings that may be in the costs in the accountant's department. Many a time I have been told that the costs are wrong. I think, however, that the accuracy of costs is much more dependent upon the people working on the physical operations, *i.e.* principally the chemists and engineers, and it should be their aim to co-operate 100 per cent with the accountant, so that the information which he requires reaches him as quickly as possible and as accurately as possible.

One final point concerns getting out one's list of allocations. That is not an operation which should fall on the accountant, it is an operation which should be a joint one between the operational departments, management, and the accountant.

C. J. Taylor: When one considers the question of providing a reserve in costs to cover extraordinary maintenance, one is faced with the problem of two different kinds of maintenance. If a refinery is of sufficient size, there is a great deal of "bread-and-butter" maintenance which, when one is working on cumulative costs, can be left to take care of itself, and one can therefore include the actual expenditure on maintenance as one goes along. I fully agree with Mr Thompson that on those occasions where the operational cycle is so long that one has to allow a substantial period of shut-down, and incur very heavy expenditure, it is extremely useful during the period of operation, to sound the warning of the total cost of the operation, by including something in the form of a reserve; equally, I feel that when that maintenance job is undertaken, then the special costs summary comes to the fore, and a separate study would indeed be made of the cumulative cost—the actual cost of the major maintenance work in comparison with the reserve which has been accumulated, and one hopes that by such a study, one can make a better reserve next time.

In regard to the use of punched cards for refinery accounting, I still regard them as a bit marginal. I agree with Mr Thompson, however, that if what is not in the accountant's control, namely the statistical data, without which one cannot begin, is produced "electronically" so that the data are presented to the accountant at a very much earlier date than normally, it would be quite wrong for the costs not to be "electronified" also. One would not only have ordinary punched cards but the very latest type, where punching is automatic from marks made on the cards. This refinement saves a good deal of time as one is not held back by the speed of the punch operator.

On the list of allocations, there could be a minor distinction but no real difference. The pure routine issue of job numbers must be in the hands of the accountant, but it is quite impossible for the accountant to lay down hard and fast rules as to when and how job numbers should be issued; he must issue them in complete agreement with the operating management.

G. R. Guest: I would like to raise two points with Mr Taylor regarding details of costing on what I suggest is ancillary equipment as opposed to actual refinery equipment.

When referring to plant, such as earth-moving equipment and drilling equipment, I believe Mr Taylor drew a distinction. On earth-moving equipment, the cost was written off against a particular job, whereas on drilling equipment, an attempt was made to keep it in service and maintain a continuous charge against a particular item, such as a hire or unit charge.

The reason I am asking this particular question is that my Company is interested in supplying products to oil companies, and we have had great difficulty in getting an indication from various concerns as to what their costs are for maintaining these particular articles.

I would be interested to know whether there is sufficient breakdown of detail to enable one to say what it is costing to maintain a particular article in one's workshop, as opposed to taking advantages of an exchange scheme, involving shipping the article back to the U.K. and replacing on an exchange basis with the manufacturer.

This scheme has been applied to some of the oil companies, whereas others have said, "It would not be worth our while because we have our workshops, and although it may be cheaper to do it your way, we prefer to keep our workshops fully employed."

I would like to know whether Mr Taylor "lumps" together the workshop costs for doing this sort of thing as an item, or whether he can ascertain the individual cost for maintaining a particular article.

The other point I am rather interested in is the cost of transportation as far as the U.K. is concerned.

Supposing that one is delivering from a depot to a

filling station, and that it costs £x to deliver 1000 gal. If one is delivering 1000 gal one mile, the transportation costs are £x, but if one delivers it twenty miles, it costs £x plus an additional amount.

As far as one's selling price of fuel is concerned, one cannot adjust the price relating to distance, but I suggest that no haulage contractor could operate a costing scheme on that basis, he would have to take mileage into account as well, and I would have thought that to find out whether one's transport is being run efficiently or not, one would have to reduce one's costing to bring in a mileage basis as well as quantity.

C. J. Taylor: In regard to the writing off of the cost of heavy equipment, it does, to a certain extent, vary according to the nature of the country and the job. When one is constructing a big scheme, such as the Kent refinery, which was constructed over a limited period of time, the contractors would have had a whole series of earth-moving plants, and their job was to do the work as quickly as possible, so that if at the end of the job the earth-moving equipment was not worth repairing, it would clearly be necessary to write that cost off as part of the construction task. If, on the other hand, one is thinking in terms of earth-moving or other equipment which is there all the time to service the refinery; to keep the roads, ditches, and so on clear—obviously, such equipment has a very much longer life. It is a permanent part of one's refinery, and one would tend then to give it a decent life, and charge it up on a rental basis. But even that is not necessarily the answer, because in the U.K. one has a maintenance service which can be contacted by telephone. In that case, one might be more inclined to hire, bring in a firm who can do the job and go out again, whereas if one is overseas, perhaps 6000 miles away from service, then it is quite clearly worth one's while setting up quite an expensive maintenance workshop, thereby keeping one's equipment "on the road."

The reason why I have suggested a slightly different treatment of drilling equipment is really only because—that whereas earth-moving equipment is more often used on a construction job, and is worn out at the end of the job, drilling equipment is always necessary, one is always drilling for testing, or drilling to maintain one's rate of production in a production area, and normally that equipment can be moved from site to site. It is rarely worked to death over a very short period, and undoubtedly one can work out the cost of maintaining that drilling equipment in good state, and spread its cost over the period during which it is used. Again, if one is 6000 miles away from a reasonable service of spares and so on, one is forced to carry the cost of one's own organization for the maintenance of that drilling equipment. The different methods of write-off are, in the examples selected, appropriate to the differing nature of the civil engineering equipment.

As far as the workshop costs are concerned, it depends to a certain extent on the amount of equipment available. In the workshops, for the proper control of the expenditure, it is necessary to have a good deal of analysis of the time that the men are engaged on the jobs. But it would not necessarily mean that once one had evaluated the workshop costs, that one would open a special account for each item of equipment. One would group them, and record the cost for a year of maintaining all the particular classes of equipment that were in each group—earth movers, welding sets, and so on—one would not normally expect to carry in one's cost records the detail of each individual welding set, for example. I doubt whether one would derive very much information from such detail, because sometimes the degree to which one works an individual welding set, if a number is at one's disposal, is quite adventitious—it is often a matter of which one in a large arc happens to be handy. In such a case, one would only allocate costs to welding sets as a whole.

G. R. Guest: Is it possible to ascertain the difference in maintenance cost, say in two competitive makes of set?

C. J. Taylor: Not through the normal method. But if one found from utilization statistics that one appeared to be getting less service out of a particular type, one would then indulge in *ad hoc* costing. Since this is a method of sampling, one would order a special check to be made over an appropriate period of two or three types; one on which there is some doubt, and another one or two for control purposes. The selection would have to be made with a view on equipment size so as not to make an unfair comparison. That kind of *ad hoc* test is one of the most valuable pieces of work that a cost accountant can do, although it involves too great a clerical effort if one always splits up the costs of all the equipment in units. This applies very much to vehicles in the distribution business, for example. It is best to group them, and then either if one has doubts, or as a matter of routine, one can, each half-year or year, select quite arbitrarily a particular type and have a special cost check made on it.

That brings me to the question raised on vehicle costs. There are two fundamentally different types of delivery. There is the bridging cost, where one is mainly concerned with the shifting of considerable loads over a good mileage, returning empty, and where the ton mileage enables one to make a useful comparison with contractors' charges. Sometimes, again, one may wish to put in an *ad hoc* test, if one is thinking in terms of the suitability of any particular type of vehicle for that operation. For the bridging operation the ton mileage cost is essential.

The question of delivery to customers, on the other hand, varies very much between areas and between countries—the colloquial expression is the "milk-round." If one is in the kind of country where the driver takes a load out, covers an indeterminate mileage, and delivers at a whole series of garages, he may select the best route, or he may not. Thus, to determine accurately the true ton mileage when a tanker load is dropped in small lots is extremely difficult. In these circumstances, where one cannot get a good regular run to depots or to large customers, the attempt to get a ton mileage figure is fraught with difficulties. If one did determine it, it might contain inaccuracies which would be misleading.

W. H. Davies: On the general question of cost accounting I am very much in agreement with all that Mr Taylor has told us. Mr Thompson, however, raised the question of the use of electronic equipment in accounting and was of the opinion that it is about time studies were made, particularly in refineries. I rather gathered that Mr Taylor has somewhat different thoughts on the subject, and therefore should like to mention that my Company has for several years been studying problems of electronic applications in the refinery. These studies take time, and when decisions are taken as to the machines required, quite a period elapses before delivery takes place. However, I am pleased to say we now have them in use and they are proving successful.

In regard to the forms of costing illustrated, these are clear and concise, but the accountant not only has to concern himself with figures but also with words which accompany statements if Management is to understand these costs, and the reasons for increases and decreases. It is therefore a frequent occurrence that the accountant not only produces figures but also has to submit an accurate and appropriately worded report.

C. J. Taylor: My only comment is that I admire the patience with which Mr Davies' Company has clearly struggled with this electronics problem, and I hope perhaps one day Mr Davies may be prepared to present a paper on the subject. I should be delighted to hear it.

M. E. Hubbard: When I was fairly young in the industry I was on the refining side, and I then formed the

impression that costs were an end in themselves and that the refiners were employed just to give the cost accountant something to work on. Now I see Mr Taylor takes a very different view and considers that costing is a service to all branches of the industry, and must be based on team work.

In my present work I am more interested in the future, and I would like to ask Mr Taylor what he feels would be the best set-up to consider the effect on costs of suggested future developments. As a first example, one is perhaps thinking of modifying some piece of plant and one wants to know what might be the future operating cost. Some elements of cost are more or less fixed, others vary in proportion to the throughput, and some follow what the engineer calls the "square root law." How would Mr Taylor set to work to analyse, and who would he ask to help in trying to establish the future cost?

The second example concerns making a material change in the size or output of a refinery. One is going to change the pattern of output, and that means a change in the pattern of distribution and of the shipment of the products. The overall financial result must bring into account not only the costs within the refinery but also the effect of this change of output on post-refinery costs.

What I want to ask Mr Taylor is how he envisages the organization to bring all these different elements into account?

C. J. Taylor: In mentioning expansion, Mr Hubbard has chosen the most obvious example of where the cost accountant has to obtain from the other parts of his organization their views as to the effect on the current position of the alterations which are envisaged. There are two different answers. Having been given the first set of data, the accountant must first relate it to current capacities, and he can then, if he has the right kind of judgment, say, "Well, this is marginal," and then work out the new cost of operations on that marginal basis, and he can very often do it with very little reference to the other parts of the organization. From his experience, he can say, "This will only mean a minor change here; it will clearly mean an addition of chemicals, and there are certain direct costs which can be put up on a straight line basis." If he has to bring in capital charges, he will clearly have to bring in the square root (or the power of 0·6) factor to make the appropriate changes in his depreciation figure. But it is very important for the cost accountant to make quite sure that those changes are, in fact, marginal. If they are of a magnitude which will clearly have major repercussions on the provision of water, or steam, or power, or would cause major changes, possibly in the arrangements of other process units, he has to get down to a great deal more detail. He must have a flow sheet showing the changed operations. He must have some indication of all the consequential alterations to other plants, particularly if this involves new plants—changed quality, for example. Then he must go to the technical man and say, "You tell me the nature and number of the people that you will want on the plant, and then I will begin to estimate the overheads and other costs which, with a change of that magnitude, will inevitably arise."

The other wider sphere, as I understand it, is supposing one wants to look, not at the refinery so much as the organization as a whole; where, in effect, one accepts that it is a major change, and one is asked not only what will be the cost of the new refining plan but also of the other changes which are going to be involved. It may, therefore, be necessary to consult straight away with the marketing side, who say, "We cannot absorb this particular increase in output over the jetties," or "We cannot absorb it by local means of distribution, we shall have to take it over the jetties." One is then confronted with the necessity for a major expansion of shipping facilities; and, in certain ports it may be necessary to consider whether there are suitable docking facilities. In that case, I imagine that the refinery accountant would only play a modest part in the cost assessment, and there would be an accountant at a different level in contact with all sides—distribution, shipping, and refining—who would have the unenviable task of trying to get from all those people who would be interested, their respective appreciation of the effect of such a change. Only when he has obtained all these data can he begin to work out a statement to show the probable return, from operations as they stand today. If one makes this major change, then the overall return will clearly be some entirely different figure. It does, in effect, depend upon how deeply into the total picture of the company's operations one really desires to make one's study.

E. J. Sturgess: On p. 43 of the paper, Mr Taylor makes a remark which is not very clear to me. "Another feature of distribution and marketing expenditure is the higher proportion, as compared with other operations, of expenditure which is inflexible in relation to the level of activity." He goes on at the end of the paragraph to say, "As standards of unit costs for control purposes are thus more difficult to establish, the employment of an annual budget estimate is of major importance."

Now, there is enough difficulty in controlling expenditure against capital budget estimates, and maintenance budget estimates, but this is an operational budget estimate, which I think was meant here. And although it may be a useful exercise to have an operational budget estimate, in many countries with inflation prevalent today, I think it is rather an academic exercise, which in many cases does not prove of very great value. I do not know whether this is Mr Taylor's experience in this matter or whether his operational budget estimates bear some relation to actual operational costs.

C. J. Taylor: The point that I was trying to make here is that it has seemed to me that, certainly as regards refining operations, there are certain amounts of expenditure which can be said to be flexible in relation to the level of activity, *i.e.* fuel consumption, chemical consumption, and things like additives are directly variable. Marketing, on the other hand, is a very much more difficult operation to fix at just the right level. There is a whole pattern of installations, depots, service stations, and transport, and even although there are major seasonal fluctuations in trade, I have never heard that one can engage and discharge labour, or alter the size of one's fleet in line with the short-term fluctuations in one's trade. One will always, perhaps, be prepared to have the staff and the equipment there to meet a rapid expansion; one never wants to be caught out by being unable to meet market demands with existing facilities. In that sense, I felt that because one is less likely to have one's distribution facilities and establishment in direct relationship with one's trade, one cannot control the cost of running it so well, by reference to a unit cost of sales, as one would be able to control it in relation to a budget. One single item, such as advertising, can only be controlled by a budget—the sky is the limit—and one must determine such an item purely as a matter of policy.

It is vital once a year to stop and take stock of what is to be the programme for the following year. The sensible thing to assume therefore is the equipment one will use, and the staff and labour that will be needed to run it. If it is more than is available, what rate of engagement will it be safe to assume? Then one can say, "We think that is what we should spend this year." I would not pretend that one could at the same time estimate for possible escalation. Always escalation has to be one of the reasons, as I see it, for one's budget not being, unfortunately, enough. However, if it is something which normally takes place in the form of wages or other type of award,

one can make a rough calculation of the necessary adjustment to one's budget; and one can then see very quickly whether, in fact, one has been unduly pessimistic about what could be done with the available labour, or whether the estimate has been too generous.

H. Hyams: There is one very small item, which is perhaps only loosely connected with cost accounting. I was very interested to hear Mr Taylor say that there was not really very much point, if one realized the limits of accuracy in carrying out cost calculations, to continue turning the handle of a calculating machine and thereby arrive at a number of meaningless decimal places. I have had experience of that in another connexion, *i.e.* in relation to the measurement of oil. In the field of calculation of bulk oil quantities, one has realized for some time what is the limit of accuracy with which one can measure a bulk quantity of oil, whether in a storage tank or in the tanker. In normal and day-to-day operations, the practical accuracy limit is of the order of about one part in a thousand, or possibly one part in two thousand. This Institute, on behalf of the British oil industry, has made its attitude on the question of the meaningless figures which appear on documents, such as bills of lading, quite clear. It is, however, peculiar that in the U.S.A. the oil accountants themselves, through the API, have indicated that they do not favour the cutting off of the number of decimal places to conform to the admitted limits of accuracy in measuring oil, this on the grounds that they apparently wish to render to the customer what they would presumably regard as a "realistic" invoice. Thus, it is not uncommon to find U.S. oil accounts' documents report quantities to two decimal places of a barrel in a large consignment when, from the angle of practical accuracy in measuring that consignment, the figure reported could not be guaranteed to be accurate to more than 1 brl, or even 10 brl.

C. J. Taylor: I appreciate Mr Hyams' point, and the observation that I should like to make is that the difficulty appears to arise, if I may say this without offence, on the selling side. The tendency is to extract the very last cent from one's customers, so that one is encouraged to assume an accuracy which I would not like to support.

On the costing side it is quite obvious that it is not very fair to ask a busy operator, who may, in fact, be moving from plant to plant, to provide an analysis of his time to the nearest ten minutes.

Dr E. B. Evans: The petroleum industry is a rather curious industry, probably owing to the immense quantity of liquid it handles. It has had to develop a new type of chemical engineering and a new hydrocarbon chemistry and it has also developed new techniques in geophysics. It seems that Mr Taylor and his colleagues have also had to develop a new approach to accountancy in order to handle the peculiar problems of the petroleum industry.

I note that on not one of Mr Taylor's tables or charts does the word "research" appear. This relieves my fears that research might be blamed for putting up the cost of all petroleum products. Neither in distribution nor refining was there any charge made for research, unless Mr Taylor has very kindly disguised it under some other heading.

We must all thank Mr Taylor very much for his excellent paper, and I hope that in the future we shall have other papers on this important subject. Our thanks are also due to Mr W. S. Thompson and others who have contributed to a very interesting discussion.

TENTATIVE STANDARD METHOD FOR THE ASSESSMENT OF THE RUST PREVENTING CHARACTERISTICS OF HARD FILM AND SOFT FILM TEMPORARY CORROSION PREVENTIVES *

By THE PROTECTIVES PANEL OF IP STANDARDIZATION COMMITTEE No. 6

THE presentation of this method (IP 153/56T) [1] as a tentative standard marks the completion of the first long programme of investigation by the Protectives Panel of the Lubricants Sub-Committee.

It may be recollected that Preston and Stroud in their paper [2] given at the Symposium on the Testing of Temporary Corrosion Preventives in 1950 described a saturated humidity test accelerated by sulphur dioxide, which could be carried out in an ordinary 5-litre beaker.

Immediately after the conclusion of the Symposium, the Protectives Panel carefully studied the valuable comments which had formed the discussion, and in due course decided that the test of Preston and Stroud described in the Symposium, and called familiarly the "CRL Beaker Test," appeared to be the test for protective properties most suitable for standardization purposes. Important features were simplicity and inexpensiveness of the apparatus.

In the meantime, the field exposure trial, by which the Panel hoped to evaluate laboratory methods, was continuing. It was found that the order of the results would form a satisfactory basis for the assessment of laboratory tests at least as far as hard- and soft-film protectives were concerned. The final report upon this trial was published in January 1954.[3]

The test, which will come to the notice of a much wider public than hitherto, is not considered suitable in its present form for oil-film protectives. It seems highly probable, however, that slight modifications in procedure, namely reduction of exposure period and reduction of SO_2 concentration, will enable the Panel to put forward a modified form of the test for oil-type protectives. Alternative tests for oil-film protectives are also being considered.

The apparatus is the same as that quoted in BS 1391 : 1952 (Performance Tests for Protective Schemes used in the Protection of Light-gauge Steel and Wrought Iron against Corrosion); the conditions of test now laid down for temporary protectives, however, differ from these for paint systems in BS 1391. A lower temperature is employed, necessitated by the low melting point of some types of solid film temporary protectives. Additionally, the sulphur dioxide is produced *in situ* from sodium thiosulphate and sulphuric acid instead of by the use of an aqueous solution of the gas; the keeping qualities of the latter are notoriously unreliable, and the former method was found to give more uniform, although slightly higher, weight losses.

It is the hope of the Protectives Panel that the publication of the test will encourage constructive criticism. It is not claimed that it is completely satisfactory, but it is at least better than a "go–no-go" test in that it will rate a series of protectives in a reproducible order which is the same as that obtained in the Field Test. Perhaps, with greater experience it may be possible to obtain a reproducible level of corrosion within acceptably narrow limits, but in the meantime it is important that the comparative nature of the test should be realized.

A large amount of work on this test has been done by members of the Panel. A summary of the results obtained on panels coated with standard weights of protective and in a test in which the sulphur dioxide was generated *in situ* is given below. Table I gives details of the protectives used and the method of application.

TABLE I

Coating of Panels

Reference	Composition of protectives	Method of application
a	DTD 121D (1 part lanolin; 2 parts white spirit)	Dip at room temperature for 5 sec, withdraw over 3 sec
b	Diluted DTD 121D (1 part lanolin; 9 parts white spirit)	As (*a*)
c (i)	Petrolatum	Dip at 170–180° for 30 sec, withdraw over 1–2 sec
c (ii)	Diluted petrolatum (29% petrolatum; 71% toluene)	As (*a*) allow to dry 30 min at room temperature, then heat in oven at 95° C for 4 min
d (ii)	Diluted inhibited petrolatum (28·4% petrolatum; 0·6% glyceryl monooleate; 71% toluene)	As (*c*) (2)
e	CS 1033B (24% rosin; 15% neutralized woolgrease; 58% coal tar naphtha; 3% special bitumen)	As (*a*)
f	CS 1033D (18% oxidized bitumen; 12% neutralized woolgrease; 19% coal tar naphtha; 51% trichlorethylene)	As (*a*)
g	Diluted CS 1033D (29% CS 1033D; 71% thinners)	As (*a*)

* MS received 4 October 1955.

USING THE "STANDARD" PROCEDURE

Reproducibility and Correlation with Field Test

Table II gives the results obtained by six laboratories in a total of twelve runs on eight panels coated with different protectives and four blanks. It will be seen that, although the repeatability and reproducibility of the losses in weight are poor, the final rankings of the various protectives are remarkably consistent and in most cases agree quite well with those obtained in the Field Test. The lack of agreement with the Field Test result on CS 1033B is noteworthy.

Repeatability

In the test described above, the panels were coated with different protectives. It was felt that it was important to know whether a number of panels coated with the same protective would show similar losses in weight. Table III gives the results obtained in three such tests. It will be seen that, generally speaking, the repeatability is good, although in some cases (notably Laboratory No. 8) the actual losses in weight are rather different from those reported in Table I.

Effect of Quality of Protective

It has been suggested that, if a large number of poorly protected panels were exposed at one time, the availability of SO_2 might be so reduced as to affect the results obtained. This was investigated by carrying

TABLE II

Seven-day Test Using Thiosulphate–Acid Method to Give 0·05 g SO_2

Reference	Protective (Ranking in Field Test)	Laboratories											
		No. 2			No. 4		No. 6		No. 7			No. 8	No. 9
a	DTD 121D (6):												
	Film wt (g)	0·071	0·086	0·076	0·085	0·09	0·095	0·099	0·108	0·101	0·104	0·09	0·08
	Wt loss (mg)	1727	619	1320	621	1250	1696	1802	1621	1647	1581	1885	2529
	Ranking	7	6	7	6	6	6	6	6	6	6	7	8
b	DTD 121D dil (8):												
	Film wt (g)	0·029	0·024	0·019	0·03	0·024	0·025	0·025	0·025	0·027	0·027	0·02	0·03
	Wt loss (mg)	1580	1240	1883	1663	2100	2262	2752	2465	2400	2503	2562	1066
	Ranking	6	7	8	8	7	7	8	7	7	7	8	6
c (i)	Petrolatum (1):												
	Film wt (g)	1·024	0·907	0·983	1·12	1·05	1·076	0·979	1·045	1·044	1·018	1·01	0·83
	Wt loss (mg)	65	58	62	70	102	132	144	83	81	88	180	265
	Ranking	1	2	2	2	2	2	2	1	1	1	3	3
c (ii)	Petrolatum dil (4):												
	Film wt (g)	0·359	0·346	0·296	0·245	0·21	0·266	0·265	0·284	0·256	0·290	0·28	0·20
	Wt loss (mg)	174	227	98	180	205	402	225	222	268	292	412	301
	Ranking	4	4	3	4	3	4	4	4	4	4	4	4
d (ii)	Petrolatum and GMO dil (5):												
	Film wt (g)	0·232	0·251	0·167	0·30	0·305	0·200	0·289	0·280	0·287	0·292	0·28	0·24
	Wt loss (mg)	116	102	131	160	185	235	219	153	162	174	123	167
	Ranking	3	3	4	3	4	3	3	3	3	3	1	2
e	CS 1033B (2):												
	Film wt (g)	0·264	0·252	0·243	0·26	0·273	0·277	0·258	0·287	0·279	0·272	0·29	0·26
	Wt loss (mg)	637	406	361	267	600	1263	673	846	804	853	986	881
	Ranking	5	5	55	5	5	5	5	5	5	5	5	5
f	CS 1033D (3):												
	Film wt (g)	0·407	0·449	0·338	0·51	0·50	0·461	0·487	0·427	0·470	0·480	0·48	0·41
	Wt loss (mg)	86	49	57	40	65	98	115	104	125	120	135	103
	Ranking	2	1	1	1	1	1	1	2	2	2	2	1
g	CS 1033D dil (7):												
	Film wt (g)	0·041	0·027	0·043	0·04	0·033	0·038	0·037	0·033	0·035	0·034	0·03	0·05
	Wt loss (mg)	2194	2050	1041	1333	2126	2718	2543	2641	2676	2540	1868	2286
	Ranking	8	8	6	7	8	8	7	8	8	8	6	7
—	Blanks—wt loss (mg)	2687	2259	2731	2501	2526	2443	2607			2390	2238	2076
		2407	1790	2774	2481	2415	2478	2492	Av.	Av.	2571	2192	2176
		2005	2640	2210	2325	2460	2323	2916	2390	2522	2608	2231	2282
		1569	1912	1266	2026	2380	2254	2471			2464	2154	2322
—	Spearman's Rank Correlation Coefficient (SRC)	0·76	0·76	0·79	0·79	0·79	0·76	0·79	0·81	0·81	0·81	0·62	0·60

TABLE III

Repeatability

Reference	Protective	Laboratory No. 6		Laboratory No. 7		Laboratory No. 8	
		Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg
b	DTD 121D	0·024	2950	—	—	0·02	2586
		0·026	2395	—	—	0·02	2786
		0·029	2368	—	—	0·02	2978
c (i)	Petrolatum	—	—	1·103	99	—	—
		—	—	1·039	82	—	—
		—	—	1·18	66	—	—
c (ii)	Petrolatum (dil)	0·267	213	0·284	194	0·30	737
		0·208	380	0·291	197	0·25	898
		0·262	287	0·275	216	0·28	880
e	CS 1033B	—	—	0·279	757	—	—
		—	—	0·259	793	—	—
		—	—	0·285	822	—	—
f	CS 1033D	0·499	140	—	—	0·46	445
		0·407	118	—	—	0·47	497
		0·419	110	—	—	0·40	547
—	Blank	—	2088	—	2376	—	2744
		—	1993	—	2626	—	3089
		—	2079	—	2564	—	2806

out tests on: (*a*) twelve uncoated panels; (*b*) eight panels coated with DTD 121 (dil) and four blanks; and (*c*) eight panels coated with CS 1033D and four blanks. The results are given in Table IV. The two sets of uncoated panels exposed at Laboratory No. 2 showed appreciably lower losses in weight than usual; this effect is, however, not confirmed by the results obtained at Laboratory No. 7. In the other tests, the losses in weight of the blank panels do not appear to be significantly affected by the quality of protective on the coated panels.

TABLE IV

Effect of Quality of Protective

Nil			DTD 121D (dil)				CS 1033D			
Laboratory No. 2		Lab. No. 7	Laboratory No. 4		Laboratory No. 7		Laboratory No. 4		Laboratory No. 7	
Wt loss, mg	Wt loss, mg	Wt loss, mg	Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg
2108	1692	1968	0·025	1490	0·025	2094	0·575	60	0·270	48
1570	1544	2166	0·022	1688	0·023	2099	0·592	69	0·302	61
1603	1376	1930	0·023	1969	0·026	2230	0·651	44	0·285	54
1573	1600	2059	0·020	1437	0·025	2073	0·538	57	0·257	60
1410	1824	1802	0·022	1697	0·027	2107	0·619	71	0·295	49
1329	1675	1697	0·021	1820	0·025	2286	0·632	71	0·303	55
1346	1697	1815	0·022	1567	0·029	2370	0·596	55	0·256	48
1540	1629	1779	0·024	1534	0·024	2339	0·577	67	0·284	57
1760	1591	2038	Blank	2596	Blank	2100	Blank	2209	Blank	2830
1658	1724	1832	Blank	2233	Blank	2184	Blank	2303	Blank	2840
1490	1767	2185	Blank	2637	Blank	2049	Blank	2141	Blank	2745
1445	1811	1949	Blank	2644	Blank	2148	Blank	2203	Blank	2729

Effect of Number of Panels

In order to determine whether the number of panels exposed at one time affected the results in any way, some tests were conducted in which only two coated and two uncoated panels were exposed. Although the results (Table V) are not conclusive, the losses in weight are similar to those obtained in previous tests (the results of Laboratory No. 8 are higher than normal—but see also Table III).

TABLE V

Effect of Number of Panels

Reference	Protective	Laboratory No. 7				Laboratory No. 8	
		Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg	Film wt, g	Wt loss, mg
b	DTD 121D (dil)	0·038	2689	—	—	—	—
		0·037	2786	—	—	—	—
c (ii)	Petrolatum (dil)	—	—	—	—	0·25	731
		—	—	—	—	0·22	1160
f	CS 1033D	—	—	0·474	56	—	—
		—	—	0·485	56	—	—
—	Blanks	—	2740	—	2695	—	3356
		—	2735	—	2846	—	3512

Edge Corrosion

In most laboratory tests—and in our own Field Test—where results are estimated visually, corrosion at the edges is ignored; in the CRL Beaker Test this,

TABLE VI

CRL Beaker Test

Seven days—thiosulphate–acid to give 0·05 g SO_2. Eight protected and two blank panels with $\frac{1}{2}$-inch rim of adhesive tape. Laboratory No. 9.

Reference	Protective	Film wt, g	Wt loss, mg	Calculated wt loss (mg) for complete area of panel	Ranking	Field rating
a	DTD 121D	0·09	1188	1830	7	6
b	DTD 121D dil	0·03	1380	2125	8	8
c (i)	Petrolatum	0·95	28	43	2	1
c (ii)	Petrolatum dil	0·27	912	1404	5	4
d (i)	Petrolatum and GMO dil	0·20	588	906	3	5
e	CS 1033B	0·30	834	1284	4	2
f	CS 1033D	0·65	23	35	1	3
g	CS 1033D dil	0·04	1146	1765	6	7
	Blank with tape	—	1242	1913	—	—
	Blank with tape	—	1263	1945	—	—
	Blank without tape	—	1634	1634	—	—
	Blank without tape	—	1638	1638	—	—

TABLE VII

CRL Beaker Test—Solid Film Protectives

Effect of light and draughts—Laboratory No. 5.

Protective	Exclusion of light and draughts					No precautions to exclude light and draughts				
	Panel no.	Film wt, mg	De-rusting method *	Wt loss/ panel, mg	Remarks	Panel no.	Film wt, mg	De-rusting method *	Wt loss/ panel, mg	Remarks
CS 1033B	2	239	(*a*)	1365	General rusting	2	262	(*b*)	1082	General rusting
	6	240	(*b*)	1031		6	266	(*b*)	1181	
	10	226	(*a*)	1050		9	233	(*b*)	1218	
CS 1033D	3	372	(*a*)	174	Rusting mainly at	3	395	(*b*)	76	Rusting mainly at
	7	360	(*a*)	125	edges with a few	7	392	(*b*)	99	edges with a few
	11	371	(*b*)	123	isolated spots near tops of panels	10	405	(*b*)	63	isolated spots near tops of panels
CS 1033D dil	4	52	(*a*)	2018	General rusting	4	43	(*b*)	1862	General rusting
	8	51	(*a*)	2023		8	41	(*b*)	2106	
	12	42	(*b*)	1808		11	37	(*b*)	1974	
Blank	5	—	(*a*)	2248	General rusting	1	—	(*b*)	1914	General rusting
	1	—	(*b*)	1999		5	—	(*b*)	1907	

* (*a*), using Clarke's solution; (*b*), using cathodic derusting.

of course, is not the case. A test was therefore conducted in which the edges of the panels were protected with adhesive tape; the results are given in Table VI. When due allowance is made for the reduced effective area of the panels, the losses in weight of the panels are comparable with those quoted in Table II. This suggests that edge-corrosion is not a problem.

Draughts and Light

Table VII, and also Table VIII where runs 11 and 12 were carried out in a cupboard to prevent draughts, show that these factors are not primarily responsible for the spread of the results.

TABLE VIII

CRL Beaker Test—Laboratory No. 1

Test	Cooling water, l/hr	Average beaker temp, °C	Loss in weight of panels, g	Corrosion rate, g/sq. metre/day	Mean corrosion rate, g/sq. metre/day	Standard deviation of the mean	Duration of test, days
1	50–55	33·6	1·219	39·6	46·9	±2·6	2
			1·562	50·7			
			1·540	50·0			
			1·458	47·3			
2	50–55	33·5	1·498	48·7	43·4	±2·9	2
			1·485	48·2			
			1·175	38·1			
			1·196	38·8			
3	80–85	34·8	1·135	36·8	34·6	±1·2	2
			1·123	36·5			
			0·979	31·8			
			1·029	33·4			
4	80–85	32·9	1·216	39·5	37·9	±0·6	2
			1·154	37·5			
			1·123	36·5			
			1·172	38·0			
5	80–85	33·1	1·197	39·9	43·8	±3·0	2
			1·172	38·0			
			1·577	51·2			
			1·418	46·0			
6	140–150	32·8	1·381	44·9	45·6	±1·5	2
			1·538	49·9			
			1·384	44·9			
			1·312	42·6			
7	140–150	33·7	1·052	34·1	38·1	±1·4	2
			1·263	41·0			
			1·186	38·5			
			1·191	38·7			
8	90–95	38·5	2·483	23·0	24·3	±0·8	7
			2·557	23·7			
			2·881	26·7			
			2·546	23·6			
9	90–95	34·5	2·268	21·0	20·4	±0·3	7
			2·158	20·0			
			2·174	20·1			
			2·123	19·7			
10	90–95	34·5	2·327	20·8	19·8	±0·6	7
			2·127	19·0			
			2·321	20·8			
			2·094	18·7			
11	90–95	33·6	1·440	46·8	50·1	±2·2	2
			1·491	48·4			
			1·745	56·6			
			1·500	48·7			
12	90–95	34·2	1·175	38·1	41·6	±1·2	2
			1·304	42·3			
			1·314	42·7			
			1·336	43·4			

Cooling Water Rate

Table VIII, which covers a series of tests done at one laboratory, shows that variation in cooling water rate does not result in a perceptible change in the corrosion rate; the spread of results is no greater than with runs using a constant amount of cooling water. Although these runs were not made when using the standard procedure, there is no reason to think that this would be significant for this particular variable.

USING MODIFIED PROCEDURES

Shorter Times of Exposure

With the object of reducing the duration of the test so that it could be completed in one working week, sets of panels were exposed for one, two, and three days instead of the usual seven. The results are shown in Table IX. The shorter exposure times

TABLE IX

One-, Two-, and Three-day Tests using Thiosulphate–Acid Method to Give 0·05 g SO_2—Laboratory No. 7

Reference	Protective (Ranking in Field Test)	1 day	2 days	3 days	3 days
a	DTD 121D (6):				
	Film wt (g)	—	—	0·101	0·096
	Wt loss (mg)	239	512	736	700
	Ranking	6	6	6	6
b	DTD 121D dil (8):				
	Film wt (g)	—	—	0·027	0·022
	Wt loss (mg)	357	936	1135	1080
	Ranking	8	8	8	8
c (i)	Petrolatum (1):				
	Film wt (g)	—	—	1·080	1·069
	Wt loss (mg)	8	24	31	28
	Ranking	3	3	3	2
c (ii)	Petrolatum dil (4):				
	Film wt (g)	—	—	0·283	0·252
	Wt loss (mg)	10	30	53	53
	Ranking	4	4	4	4
d (ii)	Petrolatum and GMO dil (5):				
	Film wt (g)	—	—	0·291	0·271
	Wt loss (mg)	7	17	34	34
	Ranking	2	2	2	3
e	CS 1033B (2):				
	Film wt (g)	—	—	0·298	0·264
	Wt loss (mg)	38	118	334	272
	Ranking	5	5	5	5
f	CS 1033D (3):				
	Film wt (g)	—	—	0·427	0·438
	Wt loss (mg)	4	11	18	18
	Ranking	1	1	1	1
g	CS 1033D dil (7):				
	Film wt (g)	—	—	0·033	0·038
	Wt loss (mg)	285	704	1019	923
	Ranking	7	7	7	7
—	Blanks (aver wt loss, mg)	504	784	1094	1042
—	SRC	0·69	0·69	0·69	0·79

would appear to offer some promise, although correlation with the Field Test is not quite as good as it is when the standard seven-day test is used.

Lower Concentrations of SO_2

Because the usual concentration of SO_2 gave rather high losses on panels coated with the poorer protectives, it was decided to try the effect of reducing it. Table X gives some results obtained using a half and a fifth of the usual concentration. The general picture is very similar to that obtained using the "standard" conditions—the laboratories do not agree on the losses in weight of the panels but the rankings show good agreement both between the different laboratories and when compared with the Field Test.

TABLE X

Seven-day Test using Thiosulphate–Acid to Give 0·025 and 0·01 g SO_2

Reference	Protective (Ranking in Field Test)	0·025 g SO_2			0·01 g SO_2	
		Laboratories				
		No. 7	No. 8	No. 6	No. 7	
a	DTD 121D (6):					
	Film wt (g)	0·091	0·09	0·109	0·111	0·120
	Wt loss (mg)	1263	1220	1059	271	312
	Ranking	6	6	6	6	6
b	DTD 121D dil (8):					
	Film wt (g)	0·030	0·02	0·028	0·030	0·030
	Wt loss (mg)	1690	1379	1875	818	789
	Ranking	8	7	7	8	8
c (i)	Petrolatum (1):					
	Film wt (g)	1·046	1·10	1·040	0·992	1·066
	Wt loss (mg)	61	230	92	27	30
	Ranking	1	1	1	1	1
c (ii)	Petrolatum dil (4):					
	Film wt (g)	0·237	0·25	0·277	0·298	0·282
	Wt loss (mg)	501	310	152	34	38
	Ranking	4	3	3	2	2
d (ii)	Petrolatum and GMO dil (5):					
	Film wt (g)	0·282	0·29	0·284	0·298	0·260
	Wt loss (mg)	191	316	143	40	48
	Ranking	3	4	2	3	3
e	CS 1033B (3):					
	Film wt (g)	0·269	0·27	0·272	0·295	0·277
	Wt loss (mg)	657	865	578	187	135
	Ranking	5	5	5	5	5
f	CS 1033D (3):					
	Film wt (g)	0·431	0·45	0·401	0·410	0·407
	Wt loss (mg)	151	259	154	60	62
	Ranking	2	2	4	4	4
g	CS 1033D dil (7)					
	Film wt (g)	0·038	0·04	0·038	0·044	0·048
	Wt loss (mg)	1542	1459	1942	585	610
	Ranking	7	8	8	7	7
—	Blanks	1862	2011	2007	1088	1159
		1815	1911	1927	1022	1287
		1768	2030	2043	1039	1160
		1717	2878	2282	1022	1076
—	SBO	0·83	0·83	0·74	0·80	0·80

Temperature Effects

Table XI shows that the range in variation of temperature during any one experiment is much greater when free circulation of air is prevented by the presence of panels. Both Tables VIII and XI show that appreciable differences in temperature may occur between different tests, and these may influence the quantitative results of the test.

TABLE XI

Variation in Temperature

Without panels	Temperature extremes,* °C	Range	Average max difference at opposite sides of beaker †
Laboratory No. 4 .	34·5–36·6	2·1	0·8
Laboratory No. 1 .	32·2–35·0	2·8	0·3
With panels			
Laboratory No. 4 .	34·0–38·1	4·1	2·7
Laboratory No. 1 .	30·2–36·5	6·3	1·3

* Neglecting the initial settling down period.

† Laboratory No. 4—readings at 15-min intervals; Laboratory No. 1—readings at ½ hr intervals.

References

1 "Standard Methods for Testing Petroleum and Its Products," 15th edition, 1956, pp. 403–7.

2 *J. Inst. Petrol.*, 1950, **36**, 457.

3 *J. Inst. Petrol.*, 1954, **40**, 32.

ALKYLTETRALINS

PART I. THE FOUR ETHYLTETRALINS*

By C. M. STAVELEY† and J. C. SMITH† (Fellow)

SUMMARY

The four ethyltetralins have been synthesized by unambiguous methods; the physical properties, including u.v. and i.r. spectra, have been measured on carefully purified samples.

As the first part of a study of the physical properties of alkyltetralins, the preparation of the four ethyltetralins in a high state of purity has been undertaken. It is expected that consistent differences in the properties of isomers will appear, for example, between tetralins with the alkyl group in the aromatic nucleus and those with the alkyl group in the reduced nucleus; it may prove possible to use these differences, especially changes in the i.r. and u.v. spectra, for the analysis of mixtures of tetralins.

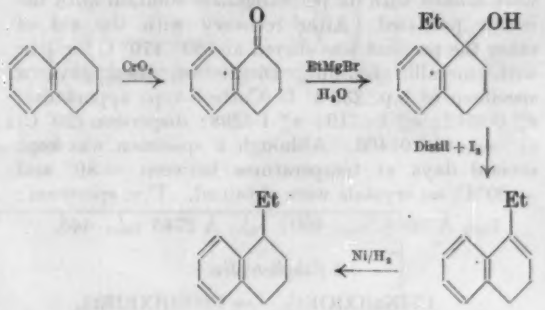
The samples of alkyltetralins described in the literature have been obtained: (1) from petroleum fractions by azeotropic, followed by fractional distillation (5- and 6-methyltetralin were thus isolated by Mair and Streiff[1]); (2) from an alkyl naphthalene by catalytic reduction, followed by thorough fractional distillation of the resulting mixture (Hipsher and Wise[2] thus obtained a series of 1-alkyltetralins); (3) by synthetic methods starting from benzene derivatives or from tetralin. If the synthesis is unambiguous there should be little difficulty in purifying the final product.

The third method is adopted in the present study of the ethyltetralins and quite different routes of synthesis are needed for each of the four isomers. Where possible, intermediates have been carefully purified and, for the final product, at each stage of the purification a measurement has been made of some physical property, especially freezing-point or i.r. absorption.

With only four compounds to consider it is not possible to generalize, but the high boiling point, refractive index, and density of the 5-ethyltetralin are interesting. In the i.r. spectra the two isomers, which are 1,2-disubstituted benzenes (1- and 2-ethyltetralin), show very strong absorption in the 12–13·5-μ region; with the trisubstituted benzenes (5- and 6-ethyltetralin) absorption in that region is much weaker.

EXPERIMENTAL

1-*Ethyltetralin*



α-Tetralone. (1) By the chromic acid oxidation[3,4] of tetralin (b.p. 89·5°–90·5° C at 20 mm and n_D^{20} 1·5393), keeping the temperature below 15° C, a crude product of b.p. 128°–132° C at 16 mm, n_D^{20} 1·5661, m.p. −2° to +2° C was obtained in approx 50 per cent yield. Crystallization from acetone at −60° C followed by distillation gave a product of n_D^{20} 1·5676, m.p. +4° to +6° C; recrystallization of this material gave pure teralone of n_D^{20} 1·5691 and m.p. 7·8°–8·0° C. Schroeter[5] recorded m.p. 7° C; Linstead and Michaelis,[6] for tetralone regenerated from the pure oxime, found b.p. 235° C at 760 mm, d_4^{20} 1·0995, n_D^{20} 1·5693.

(2) By peroxidation with air. When commercial tetralin was treated with air in the way described[7] the product could not be crystallized from acetone or light petroleum, even after seeding.

1-Ethyl-3,4-dihydronaphthalene. Ethyl bromide (61·5 g, 1·13 mol) was added slowly to magnesium turnings (137 g, 1·14 g atom). When the reaction had abated the solution was heated on the water-bath for ½ hr and then cooled in ice. α-Tetralone (m.p. 8·0° C, 73·2 g, 1 mol) in ether (125 ml) was added drop-

* MS received 27 June 1955.

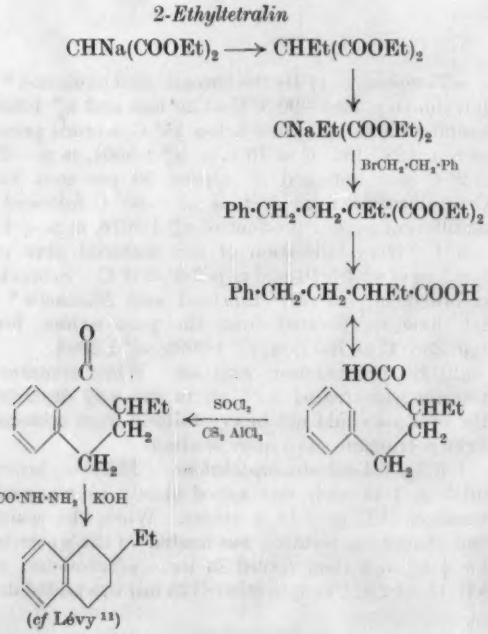
† The Dyson Perrins Laboratory, Oxford.

wise with stirring. After having stood overnight the reaction mixture was treated with dil hydrochloric acid (300 ml). During the working up the product obviously lost water; to complete the dehydration a crystal of iodine was added and heating on the water-bath continued for ½ hr. After isolation, the product distilled at 115°–120° C at 16 mm and had n_D^{20} 1·5700. (Yield, 68·9 g, 87 per cent.) Hipsher *et al.*[8] succeeded in distilling 1-ethyl-1-hydroxytetralin and then obtained the ethyldihydronaphthalene in 68 per cent yield, b.p. 72°–76° C at 1 mm, n_D^{20} 1·5730–1·5711.

1-*Ethyltetralin*. The ethyldihydronaphthalene (21·5 g) was purified for reduction by shaking in ethanol (50 ml) with Raney W7 nickel [9] (10 g). After filtration of the mixture more Raney W7 nickel (10 g) was added to the filtrate, which then rapidly absorbed hydrogen at 48 atm, completing in 1 hr at 70° C. The product boiled at 112°–113° C at 12 mm and had n_D^{20} 1·5325.

On distilling the products of two hydrogenations through a 50-cm Bower and Cooke [10] column main fractions of n_D^{20} 1·5317–1·5319 were obtained. These were shaken with dil permanganate solution until the colour persisted. After recovery with the aid of ether the product was stirred at 160°–170° C for ½ hr with metallic sodium. Distillation then gave a specimen of b.p. 239·4° C (Cottrell-type apparatus); d_4^{20} 0·9542; n_D^{20} 1·5319; n_D^{25} 1·5298; dispersion (20° C) $\mu_F - \mu_C = 0{\cdot}01466$. Although a specimen was kept several days at temperatures between — 80° and — 20° C, no crystals were obtained. U.v. spectrum: λ_{max} Å 2665, ε_{max} 460; λ_{max} Å 2745 ε_{max} 445.

2-*Ethyltetralin*



(*cf* Lévy [11])

β-*Phenylethylbromide* was prepared from β-phenylethyl alcohol (66·6 g, 0·15 mol) hydrobromic acid (240 g of 48 per cent, 1·4 mol) and conc sulphuric acid (62 g, 34 ml) by heating 4 hr under reflux. The product (90·3 g, yield 89 per cent) had b.p. 97°–100° C at 14 mm; 90° C at 11 mm; n_D^{20} 1·5573, in agreement with Perlman, Davidson, and Bogert,[12] who recorded b.p. 97° C at 14 mm and n_D^{25} 1·5543 (or n_D^{20} 1·5563, calc).

Diethyl ethylmalonate. Diethyl malonate (194 g, 1 mol) was added slowly to a solution of sodium (28 g, 1 g atm) in ethanol (500 ml). The resulting mush was stirred and ethyl bromide (132 g, 1 mol) was added slowly. After having been heated 1 hr on the water-bath the mixture was cooled, filtered from sodium bromide, and some of the alcohol evaporated. Water and ether were added: the ethereal layer was separated and then extracted with sodium hydroxide solution to remove unchanged diethyl malonate.[13] The residue after evaporation of the ether (136 g, 60 per cent yield) boiled at 89°–93° C at 15 mm and had n_D^{20} 1·4165 (Wallingford, Homeyer, and Jones,[14] 1·4170).

Diethyl ethyl-β-phenylethylmalonate. Diethyl ethylmalonate (40·7 g, 1 mol) was added dropwise to a well-stirred suspension of finely powdered sodium (5 g, 1 g atom) in dry benzene (150 ml) and the mixture gently heated to complete the reaction. β-Phenylethyl bromide (40 g, 1 mol) was added slowly and the mixture then refluxed for 2 hr, left to stand overnight and refluxed for 2 hr next day. After having been washed with water, dried, and evaporated, the benzene layer yielded, on distillation at 12·5 mm, with a Vigreux column, three fractions: (1) b.p. 92°–100° C (21 g), containing halogen; (2) 100°–178° C (3·1 g); and (3) 178°–182° C. Fraction (3) represented a 50 per cent yield of the desired ester.

Ethyl-β-phenylethylmalonic acid. The ester (32·2 g, 1 mol, of fraction (3) in ethanol (100 ml) and potassium hydroxide (18·6 g, 3·0 mol) in water (20 ml) were refluxed 4 hr, yielding in the usual way, 20·2 g (78 per cent) of acid. Crystallization from benzene gave 11·5 g of m.p. 127·5° C; a further 4·5 g of m.p. 127·5° C was obtained from the mother-liquor. Lévy [11] gave m.p. 129° C.

2-*Ethyl*-4-*phenylbutyric acid*. The malonic acid, decarboxylated in a metal-bath at 160° C (finally for 20 min *in vacuo*), gave an oil of b.p. 176° C at 10 mm, m.p. 11·5° C, n_D^{20} 1·5070 in 87–95 per cent yields. Lévy [11] gives b.p. 180° C at 16 mm and Adkins and Davis [15] give n_D^{25} 1·5010–1·5055.

The amide, prepared by the action of ammonia on the acid chloride, crystallized from water in needles of m.p. 104·5° C (Lévy [11] gives m.p. 104° C).

2-*Ethyltetralone*. (Cf *Organic Syntheses* [16]). 2-Ethyl-4-phenylbutyric acid (19·2 g, 0·1 mol) with purified thionyl chloride reacted spontaneously; after 1 hr excess thionyl chloride was removed under reduced pressure and with gentle heating.

Carbon disulphide (88 ml) was added and the mixture cooled in ice. Aluminium chloride (15 g, 0·11 mol) was added rapidly and, when the vigorous reaction had abated, the flask was warmed and shaken for ¼ hr on the water-bath. The mixture was

then cooled in ice and decomposed with ice and dil hydrochloric acid to dissolve the alumina. From the carbon disulphide a main product of b.p. 138°–145° C at 13 mm, n_D^{20} 1·5410 (yield 16·4 g, 94 per cent) was obtained. Adkins and Davis [15] give b.p. 147°–148° C at 15 mm, n_D^{25} 1·5459 (calc n_D^{20}, 1·5480), for a " faintly yellow " specimen.

The 2,4-dinitrophenylhydrazone, small red needles from ethanol, melted at 185°–186° C. (Found: C, 61·3; H, 5·1; N, 15·6 per cent. $C_{18}H_{18}O_4N_4$ requires C, 61·0; H, 5·1; N, 15·8 per cent.) The semicarbazone formed slowly; crystallized from ethanol and then from glycol monoethylether, it melted at 202°–203° C. (Found: C, 67·6; H, 7·4; N, 18·1 per cent. Calc for $C_{13}H_{17}ON_3$, C, 67·5; H, 7·4; N, 18·2 per cent.) Kloetzel and Close [17] gave m.p. 194°–196° C; Lévy [11] gave 207·5° C. Large-scale preparation: 2-Ethyltetralone (90·7 g, 1 mol) in ethanol (600 ml) was mixed with a solution of semicarbazide hydrochloride (72 g, 1·25 mol) and hydrated sodium acetate (144 g) in water (200 ml). This mixture stood for seventeen days at room temperature with occasional shaking. The crystals were removed, washed with water, and then thoroughly washed with light petroleum (b.p. 60°–80° C). When dry the residue (103·8 g, 86 per cent yield) had m.p. 195°–196° C. Crystallized systematically in batches from ethanol and then from glycol monoethyl ether it gave a product of m.p. 202°–203° C.

2-*Ethyltetralin*. Potassium hydroxide (55 g) was dissolved in ethylene glycol (400 ml + 3 ml of water). The semicarbazone of 2-ethyltetralone (66 g) was added and the mixture heated ½ hr under reflux. With the condenser set for distillation the liquid was boiled until its temperature reached 194° C and the distillate was collected. Refluxing was then resumed for 4 hr.

The solution was cooled, diluted with water, the distillate up to 194° C added, and the mixture extracted twice with ether. The extract was washed with water, with dil hydrochloric acid, and again with water. From the ethereal layer (after drying and

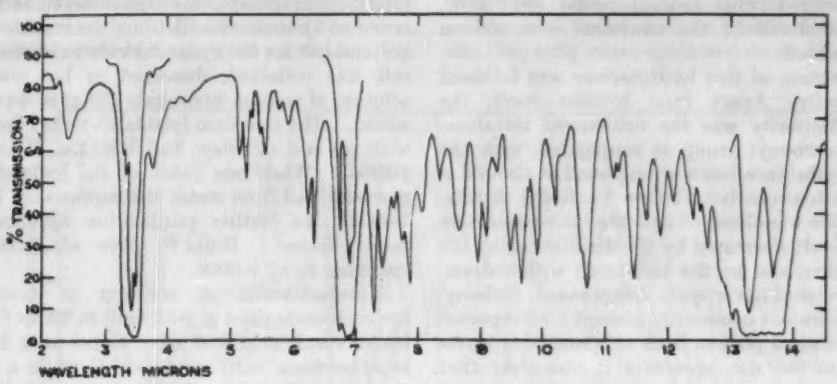


FIG 1
1-ETHYLTETRALIN

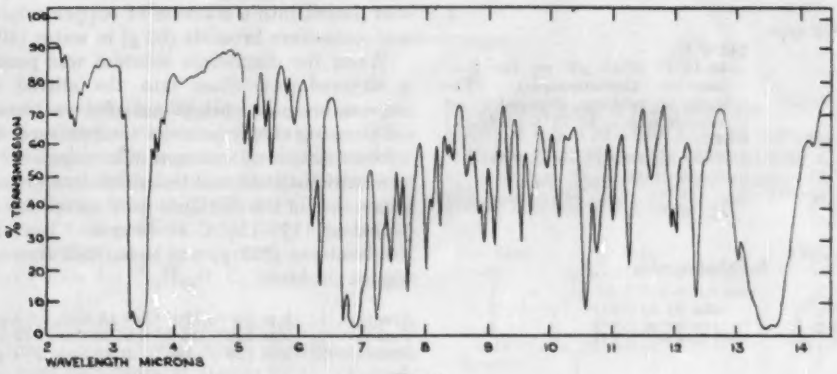


FIG 2
2-ETHYLTETRALIN

evaporating) there were obtained 37·3 g (80·5 per cent yield) of distilled product. Similar yields were obtained in the other preparations.

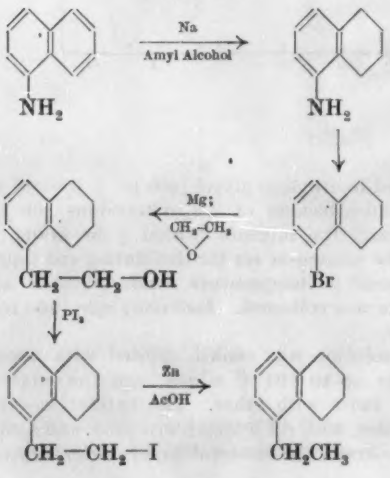
Fractionally distilled through a Bower and Cooke [10] column (a reflux ratio of 6 : 1 being used) the united crude preparations yielded a small fraction, b.p. 93·2°–100·9° C at 0·17 mm, n_D^{20} 1·5269, and then five fractions, all of b.p. 100·9° C, having n_D^{20} 1·5252–1·5253 and m.p. −49·0° to −48·3° C. These main fractions were combined, crystallized from acetone at −60° C, redistilled, stirred with sodium metal at 160° C, decanted, and distilled; the treatment with sodium was then repeated.

The purification of this hydrocarbon was followed spectroscopically. Apart from tetralin itself, the most likely impurity was the unchanged tetralone. Because its carbonyl group is conjugated with the nucleus this substance has a strong band at about 6 μ. In the crude hydrocarbon (before fractional distillation) absorption was observed at 5·93 μ; this absorption was progressively decreased by the distillation, by the recrystallization, and by the treatment with sodium. Although the band never quite disappeared, carbonyl compounds were not necessarily present: all reported spectra of tetralins possess lines at about this wavelength. From the u.v. spectrum it was clear that naphthalenic compounds, if present at all, amounted to less than 1 per cent.

The following constants of 2-ethyltetralin were recorded:

B.p. (in Cottrell-type apparatus)	242·6° C
M.p.	−48·38° C (6941 μV on the four-junction thermocouple). This form, on rubbing, changed to another of m.p. −42·75° C (6180 μV)
d_4^{20}	0·9420
n_D^{20}	1·5252; n_D^{25} 1·5231
Dispersion (20° C)	$\mu_F - \mu_C$ 0·01403
Absorption u.v. spectra	λ_{max} 2670; ϵ_{max} 546; λ_{max} 274; ϵ_{max} 633

5-*Ethyltetralin*



5-*Aminotetralin*.[18,19] A solution of 1-naphthylamine (80 g, 1 mol) in commercial "amyl alcohol" (1·2 litre) was heated to boiling (oil-bath) under a reflux condenser. Sodium (100 g, 8 g atoms or two equiv) was added at a rate sufficient to keep a vigorous reaction going.

When all the sodium had dissolved (5 hr) the solution was allowed to cool (but not sufficiently to cause solidification) and then stirred into water (1 litre) to remove sodium hydroxide. Conc hydrochloric acid (200 ml) was added to the organic layer, and the solvent removed by steam-distillation; the residue was filtered hot and left for the hydrochloride to crystallize. This salt was collected, dissolved in hot water, and a solution of sodium hydroxide (30 g) in water (200 ml) added. The free base (yields 80–90 per cent), isolated with the aid of ether, had b.p. 134° C at 9 mm, n_D^{20} 1·5906. (When one batch of the hydrochloride was recrystallized from water the regenerated base had n_D^{20} 1·5905. No further purification appeared to have been effected.) Brühl [20] gives n_D^{25} 1·58964, corresponding to n_D^{20} 1·5908.

5-*Bromotetralin*. A solution of 5-aminotetralin hydrochloride (95·4 g, 0·52 mol) in water (100 ml) and hydrobromic acid (200 ml of 48 per cent, 1·8 mol) was kept between −10° and −5° C while a solution of sodium nitrite (36·8 g, 0·54 mol) was added slowly with stirring. Cuprous bromide solution was made by dissolving in 200 ml of hydrogen bromide solution (48 per cent HBr) the precipitate formed when sulphur dioxide was passed into a solution of copper sulphate (100 g) and potassium bromide (50 g) in water (400 ml).

When the diazonium solution was passed through a sintered-glass filter into the stirred solution of cuprous bromide a bright-red solid was obtained which, on warming slowly to room temperature, decomposed with evolution of heat and of nitrogen.

Steam distillation of this reaction mixture and ether extraction of the distillate gave an oil (50–54 g) which boiled at 117°–130° C at 14 mm. The oil from five preparations (253 g) was redistilled through a 30-cm Vigreux column:

Fraction (1)	b.p. up to 124° C at 12 mm, 19·7 g, n_D^{20} 1·5766
Fraction (2)	b.p. 124°–126·5° C at 12 mm, 192·3 g, n_D^{20} 1·5816
Fraction (3)	b.p. 126·5°–130° C at 12 mm, 37·1 g, n_D^{20} 1·5831

Fractions (2) and (3) amounted to a 43 per cent yield of the bromotetralin. Smith [21] reported that this bromo-compound had b.p. 255°–257° C.

β-5-*Tetralylethanol*. 5-Bromotetralin (35·7 g, 0·17 mol) in ether (150 ml) was slowly added to magnesium (4·25 g, 0·177 equiv) and reaction was brought about by addition of iodine. When the reaction had abated the mixture was heated under reflux for 1½ hr and was then cooled in an ice-salt bath.

Ethylene oxide (30 g) was distilled through a column of soda lime and then through potassium hydroxide pellets into a flask containing ether (75 ml, cooled in ice) until the increase of weight was 25 g (0·57 mol). This solution was added slowly to the well-cooled and vigorously stirred solution of 5-tetralyl-

magnesium bromide. The reaction mixture was allowed to stand overnight; it was then heated for 1 hr under reflux, allowed to cool, and finally decomposed with 2N-hydrochloric acid (100 ml).

From the organic layer there were obtained by distillation at 9 mm pressure three fractions: (1) b.p. 49°–150° C, mainly glycol bromohydrin, (2) b.p. 125°–150° C, 3 g, (3) b.p. 150°–161° C, 18·2 g, n_D^{20} 1·5630, 18·2 g (60 per cent yield).

Previous attempts to purify this compound depended on the preparation of some derivative such as the 3,5-dinitrobenzoate.[19] It was found, however, that a specimen, dissolved in light petroleum (b.p. 60°–80° C) and cooled in CO_2 alcohol, gave crystals which did not redissolve at room temperature. Using the seeds obtained in this manner, the crude tetralylethanol was crystallized in batches from a 20 per cent solution in light petroleum (b.p. 60°–80° C) by cooling to −18° C: the final product, m.p. 53·5° C, was obtained in an overall yield of 31 per cent. (Found: C, 81·5; H, 9·0. Calc for $C_{12}H_{16}O$, C, 81·8; H, 9·1 per cent.)

The 3,5-dinitrobenzoate, from alcohol, melted at 128·5° C (128°–129° C [19, 22]). The phenylurethane, leaflets from light petroleum, melted at 87° C. (Found: C, 77·15; H, 7·0; N, 4·75. $C_{18}H_{21}O_2N$ requires C, 77·25; H, 7·1; N, 4·75 per cent.) The α-naphthylurethane crystallized from light petroleum b.p. 100°–120° C) in platelets of m.p. 124·5° C. (Found: C, 79·7; H, 6·75; N, 4·05. $C_{23}H_{23}O_2N$ requires C, 80·0; H, 6·7; N, 4·05 per cent.)

β-5-*Tetralylethyl iodide*. β-5-Tetralylethanol (20 g, 1 mol) red phosphorus (1·45 g, 0·40 g atoms) and iodine (21·6 g, 1·5 g atoms) were heated and stirred in an oil-bath at 140°–150° C for 4 hr. The cooled product was extracted four times with ether; the extracts were filtered, washed first with sodium hydroxide solution and then with water, dried, and evaporated. Distillation of the residue gave 24·8 g (76 per cent yield) of a fraction, of b.p. 148°–150° C at 1 mm, n_D^{20} 1·612. The percentage of iodine was too high. (Found: I, 47·5. $C_{12}H_{15}I$ requires I, 44·8 per cent.) In later preparations yields of 95–98 per cent were obtained.

5-*Ethyltetralin*. β-5-Tetralylethyl iodide (41·5 g) in glacial acetic acid (275 ml) was boiled under reflux while zinc dust (82 g) was added during 1½ hr. The hot solution was filtered from unchanged zinc (and zinc acetate) and was diluted with water. The zinc residue was washed thoroughly with ether and the washings used to extract the diluted filtrate (above). After the ethereal extracts had been thoroughly washed with water, sodium hydroxide solution (until alkaline) with water again and dried, evaporation and distillation gave a main fraction (22·5 g, 97 per cent yield) of b.p. 126°–130° C at 22 mm, n_D^{20} 1·5410.

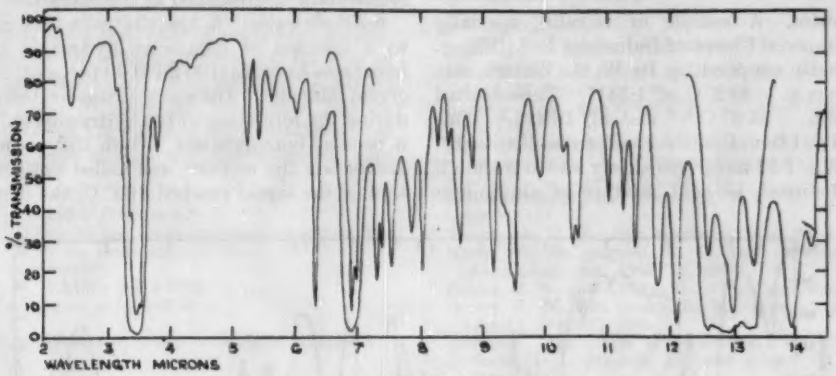


FIG 3
5-ETHYLTETRALIN

Crude 5-ethyltetralin (43·9 g) was distilled with a Bower and Cooke column [10] (reflux ratio of 20 : 1), giving the following fractions:

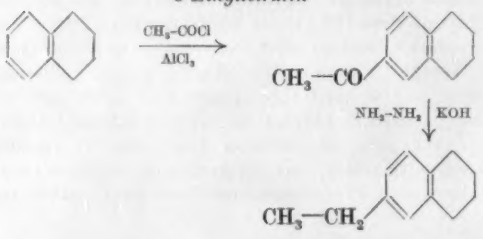
Fraction	B.p., ° C	Wt, g	n_D^{20}
0	up to 116·75 at 16 mm	—	—
1	116·75–118·0 at 16 mm	0·8	1·5396
2	118·0 at 16 mm	0·9	1·5400
3	118·0 at 16 mm	2·4	1·5400
4–11	118·0 at 16 mm	31·3	1·5400
Residue		6	1·5420

Fractions 3–11 were mixed, stirred with sodium at 160°–170° C for ½ hr, decanted, and then distilled *in vacuo*. The distillate was dissolved in three vol of acetone, crystallized at −75° C, again heated with sodium, and again distilled, yielding 28·9 g of the pure, final product. (Found: C, 90·15; H, 10·25. Calc for $C_{12}H_{16}$, C, 90·0; H, 10·0 per cent.) The constants were:

B.p. (Cottrell apparatus)	248·0° C
Fl. pt. (Rossini apparatus)	−44·7° C
n_D^{20}	1·5399; n_D^{25} 1·5379
d_4^{20}	0·9628
Dispersion (20° C)	$\mu_F - \mu_C = 0{\cdot}01403$
U.v. absorption spectrum	One maximum only, λ_{max} 2650; ϵ_{max} 245

The absorption at λ 3200, had $\varepsilon_{max} = 0{\cdot}8$, showing that the sample contained less than 0·1 per cent of naphthalene derivatives.

6-Ethyltetralin



6-Acetyltetralin. A sample of tetralin, specially distilled by Imperial Chemical Industries Ltd (Billingham) and kindly supplied by Dr W. A. Waters, was found to have m.p. −36·2° C, n_D^{20} 1·5417. The accepted values are m.p. −35·8° C [1, 8] and n_D^{20} 1·5415.[1] This tetralin (96·5 g, 1·0 mol), mixed with redistilled acetyl chloride (76·3 g, 1·32 mol), was slowly added during 2 hr to a well-stirred, ice-cold mixture of aluminium chloride (111 g, 1·13 mol) and carbon disulphide (630 ml). The mixture was allowed to warm to room temperature and to stand for 2 hr; then dil hydrochloric acid was added with vigorous stirring until two clear layers were formed. From the organic layer a fraction (118·4 g) of b.p. 105°–160° C at 14 mm was obtained. On fractionation with a 30-cm Vigreux column this gave a main fraction of b.p. 156°–158° C at 14 mm (100·6 g, 79 per cent yield) m.p. −13·1° C, n_D^{20} 1·5616.

Recrystallized twice from light petroleum in a CO_2–alcohol bath the product had the following constants: b.p. 150° C at 9 mm; m.p. −12·1° C; n_D^{20} 1·5614. A second preparation had the same constants. No recent data are recorded in the literature.

6-Ethyltetralin. 6-Acetyltetralin (110 g) was added to a solution of potassium hydroxide (138 g) and hydrazine hydrate (100 ml of 90 per cent) in diethylene glycol (500 ml). The mixture was heated under reflux during the formation of the hydrazone (45 min), when it became homogeneous. With the condenser set for distillation the mixture was boiled until the temperature of the liquid reached 195° C, the distillate being

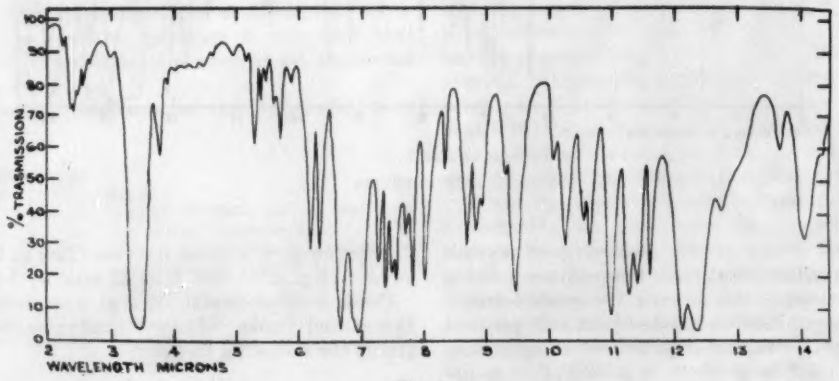


FIG 4

6-ETHYLTETRALIN

TABLE I

Alkyl tetralin	B.p., °C 760 mm	M.p., °C	n_D^{20}	n_D^t	$\mu_F - \mu_C$	d_4^{20}	Remarks	Refs
1-Ethyl	239·46	—	1·5318	—	—	0·95285	Et MgBr on tetralone	8
	239·40	—	1·5316	—	—	0·95290	Hydrogenation of 1-Et naphthalene	2
	237–238	—	—	n_{5875}^{25} 1·52999	—	d_4^{25} 0·9498–0·9511	Cyclization of Ph hexanols	24
	239·4	—	1·5319	n_D^{25} 1·5298	0·01466	0·9530	Present work	
2-Ethyl	235·5 at 731	—	—	$n_D^{15·5}$ 1·5250	—	$d_4^{15·5}$ 0·9401	From 2-Et tetralone	11
	242·7	−48·38	1·5252	n_D^{25} 1·5231	0·01403	0·9420	Present work	
		−42·75						
5-Ethyl	248·02	−44·55	1·5398	—	—	0·96286	Hydrogenation of 1-Et naphthalene	2
	248·0	−44·70	1·5399	n_D^{25} 1·5379	0·01403	0·96283	Present work	
	247·8							
6-Ethyl	239·5 at 736	—	—	$n_D^{15·5}$ 1·5350	—	$d_4^{15·5}$ 0·9608	From 6-Et tetralone	11
	241·5–243·5 at 739	−70	1·5388	—	—	0·9529	From tetralin, EtCl, $AlCl_3$	25
	246·4	*ca* −60	1·5322	n_D^{25} 1·5300	0·0155	0·94606	Present work	

collected. Refluxing was then resumed and, at the end of 4 hr, the mixture (now in two layers) was allowed to cool, diluted with water and the distillate up to 195° C added. The product, isolated with the aid of ether, had b.p. 103·5° C at 9 mm, n_D^{20} 1·5321, and the yield was 97·5 g (96 per cent).

On distillation through a 40-cm Purdue "Spiral Screen" column [23] at 8 mm pressure and a reflux ratio of 6 : 1 the following fractions were obtained :

No.	B.p., ° C	n_D^{20}	Wt, g
0	up to 98·75	—	trace
1	98·75–102·0	1·5322	3
2	102·0 –102·75	1·5321	5·9
3	102·75 const	1·5320	64·4
4	102·75–103	1·5321	7·4
5	Residue	1·5339	6·8

In order to obtain a specimen of maximum purity, fraction (3) was stirred with sodium metal for ½ hr at 160°–170° C, and the liquid then distilled *in vacuo*. The product could be made to crystallize, but its melting point was too low to allow crystallization from a solvent. The pure sample had the following constants :

B.p. . . . 246·5° C (Cottrell)
Fl. pt. . . Could not be determined accurately but lay between −60° and −54° C
d_4^{20} . . . 0·9460
n_D^{20} . . . 1·5322; n_D^{25} 1·5300
Dispersion (20° C) $\mu_F - \mu_C = 0·0155$

The u.v. absorption spectrum had three maxima :

λ_{max} 2650; ε_{max} 477;
λ_{max} 2700; ε_{max} 690;
λ_{max} 2790; ε_{max} 759.

COMMENTS ON THE INFRA-RED SPECTRA

By Dr F. B. Strauss

In the 6·2–6·4-μ region (double bond vibrations) the two *ortho*-disubstituted benzene derivatives (1- and 2-ethyltetralin) show a doublet at 6·24 and 6·34 μ. The 1,2,4-substituted benzene (6-ethyltetralin) also has a doublet, at 6·20 and 6·34 μ. In contrast the 1,2,3-isomer (5-ethyltetralin) has a single line 6·31 μ.

More important are the out-of-plane vibrations of the (aromatic) hydrogen atoms in the 12–13·5-μ region. The two *ortho*-disubstitution compounds show very strong absorption in this region : only with a thin film (0·01 mm) do individual lines appear, and the main line 1-ethyltetralin is at 13·29 μ. Absorption in this region is much less for the tri-substituted benzenes. The 1,2,3-compound (5-ethyltetralin) absorbs at 12·99 μ, while the 1,2,4-isomer (6-ethyltetralin) has a doublet at 12·13 and 12·15 μ.

ACKNOWLEDGMENTS

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TEMPERATURE DEPENDENCE OF THE VISCOSITY OF LIQUIDS, ESPECIALLY LUBRICATING OILS *

INTRODUCTION OF THE FUNDAMENTAL VISCOSITY TEMPERATURE INDEX F.V.T.I.

By J. CORNELISSEN † and H. I. WATERMAN † (Hon. Fellow)

SUMMARY

The formula $\log \nu = (A/T^x) + B$ is applied to a series of lubricating oils and five silicones. An index based on a rational method is described for indicating the temperature dependence of the viscosity of these lubricating oils and silicones. The same method may be used to indicate the temperature dependence of the viscosity of other liquids and oils. The method is proposed to replace several existing methods.

INTRODUCTION

In a previous communication [1] a new formula indicating the viscosity–temperature relationship was introduced :

$$\log \nu = (A/T^x) + B \quad . \quad . \quad . \quad (1)$$

ν = kinematic viscosity in cS; 1 cS = 0·01 Stokes; Stokes = cm^2/sec.
T = absolute temperature ° K.
A, B, and x are constants.

It was claimed that the formula was valid for a variety of substances, single liquid compounds as well as mixtures of substances, *e.g.* lubricating oils. For the lubricating oils graphs were given, showing straight lines representing the viscosity–temperature relationship according to $\log \nu = f(1/T^{3\frac{1}{2}})$, *cf* Figs 4 and 5 of this paper. The value of x was chosen to be 3·5, being the average value of 3–4 for these oils, see Table II. For the silicones the value of x was chosen to be 1·0, see Table III. In Fig 6, the viscosity measurements of the silicones are graphically represented by straight lines.

In this paper formula (1) is applied to the series of lubricating oils and the silicones for indicating the viscosity–temperature dependence by means of an index. The most exact way of doing this is to calculate the value of $(d\nu/dt)$ for a particular temperature (or viscosity) of the liquid. But the value of this quantity generally changes with viscosity or temperature, and thus comparison between various liquids is made difficult. This can be made clear by the following consideration :

From equation (1) it follows by differentiating

$$(d\nu/\nu) = -x \,.\, (a/T^{x+1}) \,.\, dT \qquad a = 2{\cdot}30\,A$$

or

$$(d\nu/dT) = -(a \,.\, x \,.\, \nu)/(T^{x+1}) \quad . \quad . \quad (2)$$

From equation (1) it follows that

$$\nu = 10^{[(A/T^x)+B]}$$

Substitution of this expression in (2) gives

$$(d\nu/dT) = [-a \,.\, x \,.\, 10^{(a/T^x)+B}]/T^{x+1} \quad . \quad (3)$$

From equation (3) it can be seen that the expression $(d\nu/dT)$ is dependent on the temperature. (If T is eliminated from equation (2) the same thing is true for the dependence of the expression $(d\nu/dT)$ on the viscosity.) This conclusion also follows from the diagram representing $\nu = f(T)$, Fig 1. $tg\alpha$ is different from $tg\beta$, *i.e.* the value of $(d\nu/dT)$ at temperature T_1 is different from the value $(d\nu/dT)$ at temperature T_2.

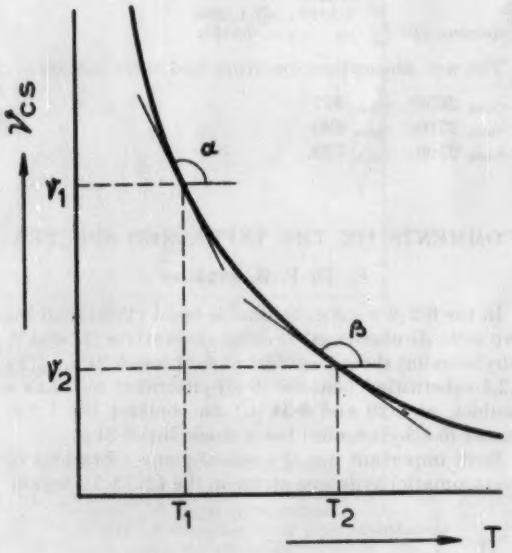


Fig 1

SCHEMATIC REPRESENTATION OF THE FUNCTION $\nu = f(T)$

In the literature many attempts were made to find an index (relative or absolute) indicating the temperature dependence of the viscosity of lubricating oils. One of the first attempts was made by Dean and

* MS received 31 August 1955.

† Delft University, Holland.

Davis,[2] who introduced the Viscosity Index (V.I.), defined as

$$\text{V.I.} = [(L - U)/(L - H)] \cdot 100 \quad . \quad (4)$$

U = viscosity (S.S.U.) at 100° F of the oil under examination.

L = viscosity (S.S.U.) at 100° F of a member with the same viscosity at 210° F as the oil under examination, of a standard series of lubricating oils with relatively great temperature dependence of the viscosity.

H = viscosity (S.S.U.) at 100° F of a member with the same viscosity at 210° F as the oil under examination, of a standard series of lubricating oils with relatively small temperature dependence of the viscosity.*

Some of the objections against this method are

(1) The method is not exact.

(2) The method gives anomalous results at higher values of V.I. (V.I. > 140).

An improvement of the V.I. method has been given by Blott and Verver.[5] These authors proposed the Viscosity Modulus (V.M.) :

$$\text{V.M.} = [(\log L - \log U)/(\log L - \log H)] \cdot 100 \quad (5)$$

Symbols L, U, and H are synonymous with those above.

This method, however, gives no solution for objection (1) to the V.I. method described above. Many other investigators have endeavoured to provide a suitable method which expresses the temperature dependence of the viscosity, *e.g.* Ramser [6] and Göttner,[7] who proposed the average value of the expression $(1/\nu)/(d\nu/dT)$, and Whalley and Leach,[8] and Kobeko and Shishkin,[9] who proposed the average value of the expression $(1/\nu)\left(d\nu \Big/ d\frac{1}{T}\right)$, both over an arbitrary temperature range.

Ubbelohde [10] proposed the Viscosity Pole Height (V.P.H.). The method is based on the assumption that ν–T lines for lubricating oil fractions, obtained from one crude oil, in a diagram representing

$$\log \log (\nu + 0{\cdot}8) = f(\log T) \quad . \quad . \quad (6)$$

form a fan of straight lines radiating from a single point (at low temperature). The ordinate of this point is called the V.P.H.

Other methods have been published, but are not repeated here. A good survey of the various methods is given by Blott and Verver.[5]

FUNDAMENTAL VISCOSITY TEMPERATURE INDEX

A new index is introduced, expressing the temperature dependence of the viscosity. The index has a rational and exact basis, which is the formula

$$\log \nu = (A/T^x) + B \quad . \quad . \quad . \quad (1)$$

The method comprises the following essential points. As appeared in a previous communication,[1] the exponent x may have any value ranging from approximately 1 to 5 for various liquids, but it is permissible to take the nearest integral value of x for interpolation purposes, provided the temperature range is not too large. In this way, a number of (lubricating) oils may be classified in one group, *i.e.* the group of oils having the same (or nearly the same) value of x.

The value of A for one group of oils (with the same nearby value of x) is an absolute index indicating the temperature dependence of the viscosity of oils.

A more practical index for indicating the temperature dependence of the viscosity is the value of $\log (\nu_{20}/\nu_{70})$, where ν_{20} = viscosity in cS at 20° C and ν_{70} = viscosity in cS at 70° C (other temperatures instead of 20° C and 70° C may be chosen).

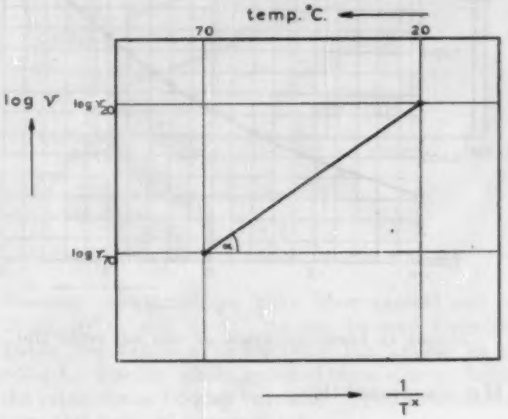


FIG 2

SCHEMATIC REPRESENTATION OF THE FUNCTION $\log \nu = f(1/T^x)$

It follows from Fig 2 that

$$A = tg\alpha = (\log \nu_{20} - \log \nu_{70})/(1/T_{20}^x) - (1/T_{70}^x)$$

or $$\log (\nu_{20}/\nu_{70}) = [(1/T_{20}^x) - (1/T_{70}^x)]A$$

If the members of a particular group of oils have about the same value of the exponent x, then $(1/T_{20}^x) - (1/T_{70}^x)$ is constant. Therefore $\log (\nu_{20}/\nu_{70}) = \text{Constant} \times A$. In this group of oils $\log (\nu_{20}/\nu_{70})$ is a practical index. It is also an absolute index as is A. Both express the viscosity–temperature dependence of the oils. The authors propose for practical reasons to use $\log (\nu_{20}/\nu_{70})$ and to call it " Fundamental Viscosity Temperature Index " (F.V.T.I.).

If the value of x for another group of oils appears to be different from that of the prior mentioned group, the values of $\log (\nu_{20}/\nu_{70})$ (the F.V.T.I.) of the two groups can obviously not be directly compared. Besides the F.V.T.I., the value of the viscosity at some

* There are further revisions and additions to the original Dean and Davis method.[3, 4]

temperature, *e.g.* ν_{20}, has been given. This is seen in Tables II * and III.

CALCULATION OF THE VALUE OF x

Formula (1) contains three constants: A, B, and x. Three viscosity measurements ν_1, ν_2, and ν_3 at temperatures T_1, T_2, and T_3, respectively, have to be made to calculate the constants.

The following equation can be derived [1]

$$(\log \nu_1 - \log \nu_2)/(\log \nu_2 - \log \nu_1) = [(1/T_1^x) - (1/T_2^x)]/[(1/T_2^x) - (1/T_3^x)] \quad (7)$$

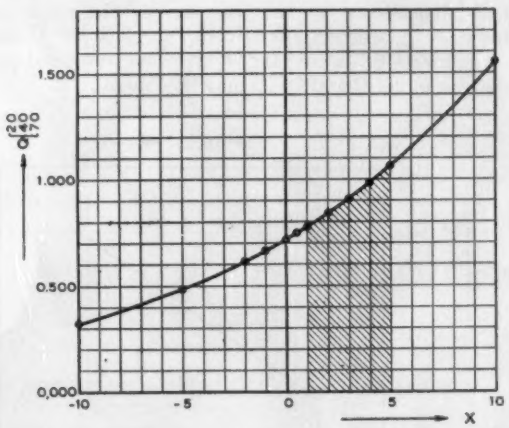


FIG 3

GRAPHICAL REPRESENTATION OF THE EQUATION (7b)

If it is supposed that

$$Q = (\log \nu_1 - \log \nu_2)/(\log \nu_2 - \log \nu_3) \quad (7a)$$

then

$$Q = [(1/T_1^x) - (1/T_2^x)]/[(1/T_2^x) - (1/T_3^x)] \quad (7b)$$

Q can be calculated by means of equation (7b) for various values of x and known temperatures, *e.g.* $T_1 = 293°$ K (20° C), $T_2 = 313°$ K (40° C), and $T_3 = 343°$ K (70° C). Results are shown in Table I.

TABLE I

Q {20 40 70	x
0·76	0·7
0·78	1·0
0·84	2·0
0·91	3·0
0·98	4·0
1·06	5·0

The value of Q can also be calculated from equation (7a) if ν_1, ν_2, and ν_3 are known. On the other hand, x may be read from Table I if Q has been calculated in this way. Instead of using a table it is also possible to use a diagram representing $Q = f(x)$ in Fig 3. The part of the curve on top of the shaded region is of practical importance. For another set of temperatures than those mentioned above, another diagram must be constructed.

EXPERIMENTAL PART

In Table II data of twenty-five undoped lubricating oils are given. Viscosity measurements have been made at 20° C, 40° C, and 70° C by means of the Wi. Ostwald viscometer with improvements by Sprokel.[11]

As can be seen from the Table, the values of x for these oils appear to be 3–4.

TABLE II

Lubricating oil number	ν_{20}° C, cS	$\log \frac{\nu_{20}}{\nu_{70}}$ = F.V.T.I.	V.I.	x
1	150·1	0·936	115	3·1
2	177·2	0·985	105	3·4
3	1,614	1·333	90	3·1
4	1,105	1·439	38	4·0
5	2,215	1·592	19	3·9
6	2,064	1·590	12	4·1
7	10,800	1·887	7	4·0
8	—	—	—	—
9	224·0	1·092	76	3·6
10	501·5	1·279	48	3·8
11	808	1·308	61	3·6
12	6,760	1·501	80	4·2
13	458·1	1·212	71	3·5
14	594·3	1·270	68	3·5
15	936	1·389	47	3·9
16	1,224	1·365	72	3·3
17	2,426	1·387	95	3·2
18	187·3	1·006	105	3·3
19	344·2	1·096	94	3·3
20	440·8	1·130	103	3·0
21	737	1·211	96	3·1
22	902	1·232	98	3·2
23	1,318	1·288	97	3·1
24	2,233	1·366	98	3·4
25	4,340	1·443	90	3·6
26	8,970	1·582	80	4·0

The F.V.T.I. varies from 0·94 to 1·89 (group value of x is 3·5).

TABLE III

Silicone	ν_{20}° C, cS	$\log \frac{\nu_{20}}{\nu_{70}}$ = F.V.T.I.	x
A	64·83	0·368	1·0
B	143·1	0·371	1·1
C	410·2	0·375	0·7
D	1393	0·378	0·9
E	6400	0·370	0·8

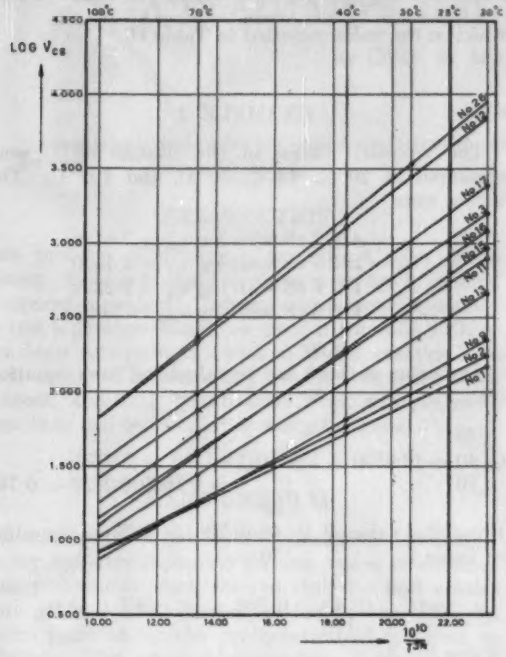
The F.V.T.I. varies from 0·37 to 0·38 (group value of x is 1).

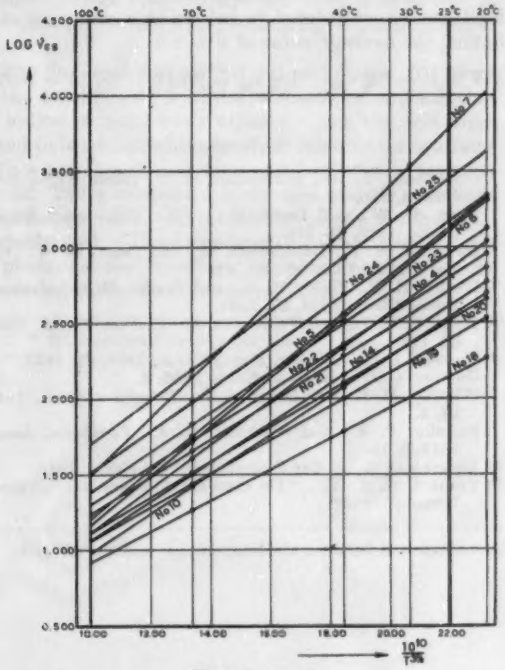
For the whole group of lubricating oils the value of x may therefore be chosen to be equal to 3·5;

* For the interest of the reader the authors have included in Table II the V.I. of the oils.

then no deviation from the average value of x exceeds 0·5.

In Table III data of five silicone oils are given.





FIGS 4 AND 5

LOG ν V. $1/T^{3.5}$ FOR A SERIES OF LUBRICATING OILS

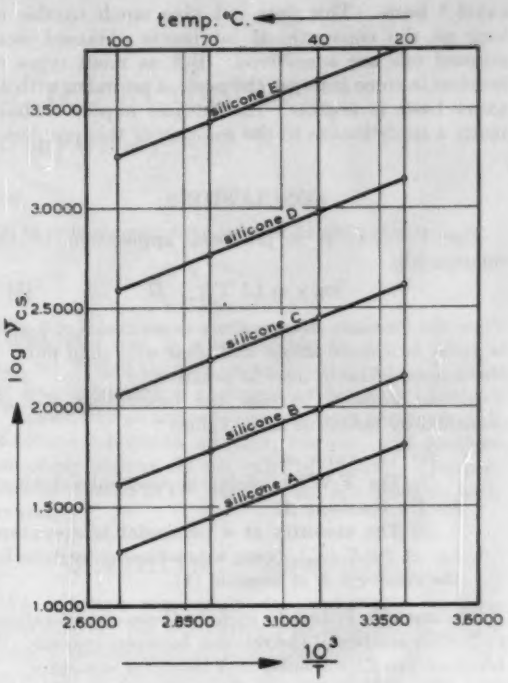


FIG 6

LOG ν V. $1/T$ FOR A SERIES OF SILICONE OILS

Viscosity measurements have been carried out at 20° C, 40° C, and 70° C. As can be seen from the Table, the values of x for these oils appear to be 0·7–1·1. For the whole group of these silicone fluids, the value of $x = 1{\cdot}0$ may be taken. Then no deviation from this value of x exceeds 0·5.

From Table II it can be seen that, *e.g.* oil number 24 is of definitely better quality than oil number 5; both these oils have the same viscosity (about 2200 cS at 20° C), whereas the values of F.V.T.I. are 1·366 and 1·592, respectively.

From Table III it follows that for the five silicone oils considered ν_{20} varies from 65 to 6400 cS; contrary to the lubricating oils summarized in Table II the F.V.T.I. is almost constant.

Direct comparison of these silicone oils with the hydrocarbon lubricating oils is not possible because of the different values of x for both series.

The constancy of the F.V.T.I. values of the silicone oils also follows from Fig 6, representing $\log \nu = f(1/T)$ in which the straight lines are running practically parallel.

Generally, a high viscosity value at 20° C is connected with a high value of F.V.T.I., *e.g.* lubricating oil number 7 has a F.V.T.I. = 1·887 (Table II). Low viscosity oils usually have a low value of F.V.T.I., *e.g.* the numbers 1 and 2 have a F.V.T.I. value <1, Table II (*cf* Figs 4 and 5).

As has already been pointed out on p. 63, one of the severe shortcomings of the V.I. is that it lacks an

exact * basis. This does not give much trouble as long as the conventional lubricants obtained from mineral oils are considered. But as more types of lubricants come into use the need of an index with an exact basis is urgent. The authors expect to have made a contribution to the solution of this problem.

CONCLUSIONS

The F.V.T.I. is a practical application of the relationship

$$\log \nu = (A/T^x) + B \quad . \quad . \quad . \quad (1)$$

Thus the viscosity–temperature dependence of liquids is given in a more sound and clear way than most of the indices hitherto used in practice.

In the authors' system the lubricating oils are classified by means of three values :

(1) The value of x.

(2) The F.V.T.I., being a practical substitute for the constant A.

(3) The viscosity at a particular temperature, *e.g.* at 20° C (ν_{20}), being a practical substitute for the constant B of formula (1).

The authors intend to include these considerations in further studies of the relation between viscosity, its temperature dependence, and chemical structure.

EXAMPLE 1

The viscosity values of oil number 16 were measured at 20° C, 40° C, and 70° C. The values were

$\nu_{20} = 1224$ cS with $\log \nu_{20} = 3{\cdot}0878$,
$\nu_{40} = 268{\cdot}7$ cS with $\log \nu_{40} = 2{\cdot}4293$,
and $\nu_{70} = 52{\cdot}82$ cS with $\log \nu_{70} = 1{\cdot}7228$.

The value of $Q\begin{cases}20\\40\\70\end{cases}$ can be calculated from equation (7a)

$$Q\begin{cases}20\\40\\70\end{cases} = (3{\cdot}0878 - 2{\cdot}4293)/(2{\cdot}4293 - 1{\cdot}7228) = (0{\cdot}6585/0{\cdot}7065) = 0{\cdot}932.$$

From this value of $Q\begin{cases}20\\40\\70\end{cases}$ it follows according to Table I

$$Q\begin{cases}20\\40\\70\end{cases} = 0{\cdot}932 \quad x = 3{\cdot}3 \text{ (}cf\text{ also Fig 3).}$$

The value of the exponent x is 3·3; it can be said that the oil belongs to the group of lubricating oils having an average value of $x = 3{\cdot}5$.

The viscosity–temperature dependence embodied in the F.V.T.I. is given by

$$\text{F.V.T.I.} = \log \nu_{20} - \log \nu_{70} = 3{\cdot}0878 - 1{\cdot}7228 = 1{\cdot}365,$$

which is the value reported in Table II.

EXAMPLE 2

The viscosity values of the silicone oil C were measured at 20° C, 40° C, 70° C, and 100° C. The values were

$\nu_{20} = 410{\cdot}2$ cS with $\log \nu_{20} = 2{\cdot}6130$
$\nu_{40} = 282{\cdot}5$ cS with $\log \nu_{40} = 2{\cdot}4510$
$\nu_{70} = 172{\cdot}9$ cS with $\log \nu_{70} = 2{\cdot}2378$
$\nu_{100} = 115{\cdot}2$ cS with $\log \nu_{100} = 2{\cdot}0615$

The value of $Q\begin{cases}20\\40\\70\end{cases}$ can be calculated from equation (7a)

$$Q\begin{cases}20\\40\\70\end{cases} = (2{\cdot}6130 - 2{\cdot}4510)/(2{\cdot}4510 - 2{\cdot}2378) = 0{\cdot}1620/0{\cdot}2132 = 0{\cdot}760$$

From this value of $Q\begin{cases}20\\40\\70\end{cases}$ (0·760) it follows according to Table I

$$Q\begin{cases}20\\40\\70\end{cases} = 0{\cdot}760 \quad . \quad x = 0{\cdot}7$$

cf also Fig 3.

The value of the exponent x is 0·7; the silicone fluid can be considered to belong to a group of oils having the average value of $x = 1{\cdot}0$

$$\text{F.V.T.I.} = \log \nu_{20} - \log \nu_{70} = 2{\cdot}613 - 2{\cdot}238 = 0{\cdot}375$$

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* Not exact because the V.I. method does not make use of the real relation between the temperature and the viscosity.

A QUALITATIVE TEST FOR TEL IN GASOLINE*

By GEO. E. MAPSTONE† (Fellow)

SUMMARY

A new simple qualitative test sensitive to 0·01–0·02 ml/gal has been developed for the detection of TEL in gasoline samples.

INTRODUCTION

THE problem of detecting, as distinct from determining, TEL in a gasoline appears to have suffered comparative neglect. It is not uncommonly necessary to test a gasoline sample to see if it contains TEL or has been contaminated with a leaded gasoline. In such cases, it is customary to determine the TEL content, and such quantitative work requires more time than can be justified in many instances.

EXPERIMENTAL

A number of reagents were examined for their suitability but were discarded for one reason or another. This preliminary work showed that the best results were given by the decomposition of the TEL by iodine followed by the precipitation of the lead as sulphide. The initial decomposition of the TEL by iodine at room temperature was very slow except in the presence of sunlight, indicating a photochemical effect.

The final test was carried out as follows: To 10 ml of the gasoline add 5–10 drops of a 2 per cent solution of iodine in anhydrous ethanol. Let the test tube stand in bright sunshine for 5–10 minutes (or irradiate with a u.v. lamp), and then add 1 ml of solution containing 200 g of sodium hydroxide and 50 g sodium sulphide per litre. Shake till the colour of the iodine is discharged. The formation of a black film of lead sulphide at the interface between the two liquid layers indicates the presence of TEL.

SENSITIVITY

With this test it was possible to detect readily 0·02 ml TEL/I.G. and possibly 0·01 ml/gal. The gasoline composition appeared to have no effect on the sensitivity as the same results were obtained with *iso*-octane–*n*-heptane mixture, benzole, and gasoline containing approx 50 per cent of olefins. The presence of ethanol in the gasoline did not interfere with the test.

QUANTITATIVE APPLICATION

An attempt was made to apply this reaction quantitatively but even after 7 hr exposure to direct sunlight decomposition was incomplete. Moreover, the weight of precipitate at the end of that time was 119 per cent of the possible amount of lead iodide from a gasoline containing 2 ml TEL/gal. The precipitate was only partly soluble in boiling water confirming the supposition that it was not pure lead iodide. However, the water insoluble fraction blackened immediately with sodium sulphide showing that the formation of lead iodide was not essential to the application of the qualitative test.

ACKNOWLEDGMENTS

The author wishes to acknowledge with thanks the permission granted by the management of the South African Torbanite Mining and Refining Co Ltd, for permission to publish this note, and the assistance of Miss D. A. M. Holmes in carrying out the work.

* MS received 5 September 1955.

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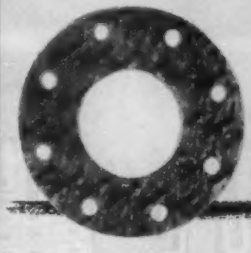

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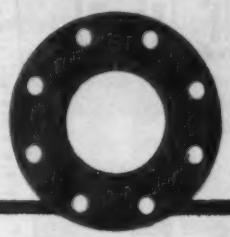

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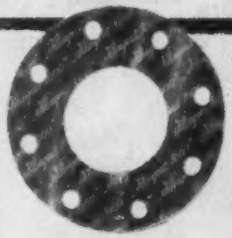

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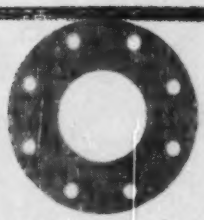

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17	148	220	327	490	686										
18	157	264	367	484	630	800									
19	166	257	377	550	665	845	1050								
20	175	271	387	538	700	889	1105	1330	1580	1850	2140	2450	2800	3170	
21	184	286	417	594	726	924	1140	1380	1640	1940	2240	2530	2940	3330	
22	193	300	437	591	770	978	1196	1455	1740	2030	2350	2700	3080	3480	
23	201	313	457	617	800	1029	1250	1520	1820	2130	2460	2830	3220	3640	
24	210	327	476	644	840	1080	1305	1590	1900	2220	2570	2950	3360	3800	
25	218	300	496	672	875	1110	1360	1655	1980	2310	2670	3075	3500	3960	
26		354	516	697	909	1150	1400	1725	2060	2410	2770	3200	3640	4120	4600	5100	5650
27		367	536	726	945	1196	1470	1785	2140	2500	2880	3320	3780	4280	4780	5300	5870
28		381	556	751	980	1240	1505	1850	2220	2590	2990	3440	3920	4430	4950	5500	6090
29		395	576	778	1015	1285	1560	1920	2290	2680	3090	3570	4060	4580	5140	5710	6330
30		409	596	804	1050	1330	1615	1985	2375	2780	3200	3690	4200	4750	5300	5910	6540
31			616	831	1085	1375	1670	2050	2460	2870	3310	3820	4340	4900	5480	6110	6780
32			635	858	1120	1415	1745	2130	2530	2980	3410	3930	4480	5060	5660	6310	6980
33			655	885	1155	1460	1800	2180	2610	3050	3520	4060	4620	5220	5840	6500	7200
34			675	912	1190	1505	1853	2300	2690	3140	3630	4180	4760	5380	6020	6700	7420
35			695	940	1225	1550	1910	2315	2770	3240	3730	4300	4910	5540	6200	7100	7660
36				968	1260	1595	1965	2380	2850	3330	3840	4430	5060	5690	6380	7100	7880
37				991	1296	1640	2020	2450	2930	3430	3945	4560	5190	5860	6560	7290	8070
38				1013	1330	1685	2070	2510	3010	3510	4050	4670	5340	6000	6730	7490	8280
39				1045	1365	1725	2125	2580	3080	3600	4150	4800	5470	6180	6900	7690	8500
40				1072	1400	1770	2180	2645	3170	3705	4280	4930	5610	6320	7170	7890	8730
41					1435	1815	2240	2719	3260	3790	4390	5050	5750	6480	7250	8090	8950
42						1860	2290	2780	3335	3890	4470	5150	5880	6640	7430	8320	9190
43						1905	2342	2840	3400	3980	4570	5290	6020	6800	7600	8480	9380
44						1950	2400	2910	3490	4070	4680	5410	6160	6960	7780	8670	9600
45						1995	2450	2980	3570	4160	4800	5540	6300	7110	7980	8870	9820

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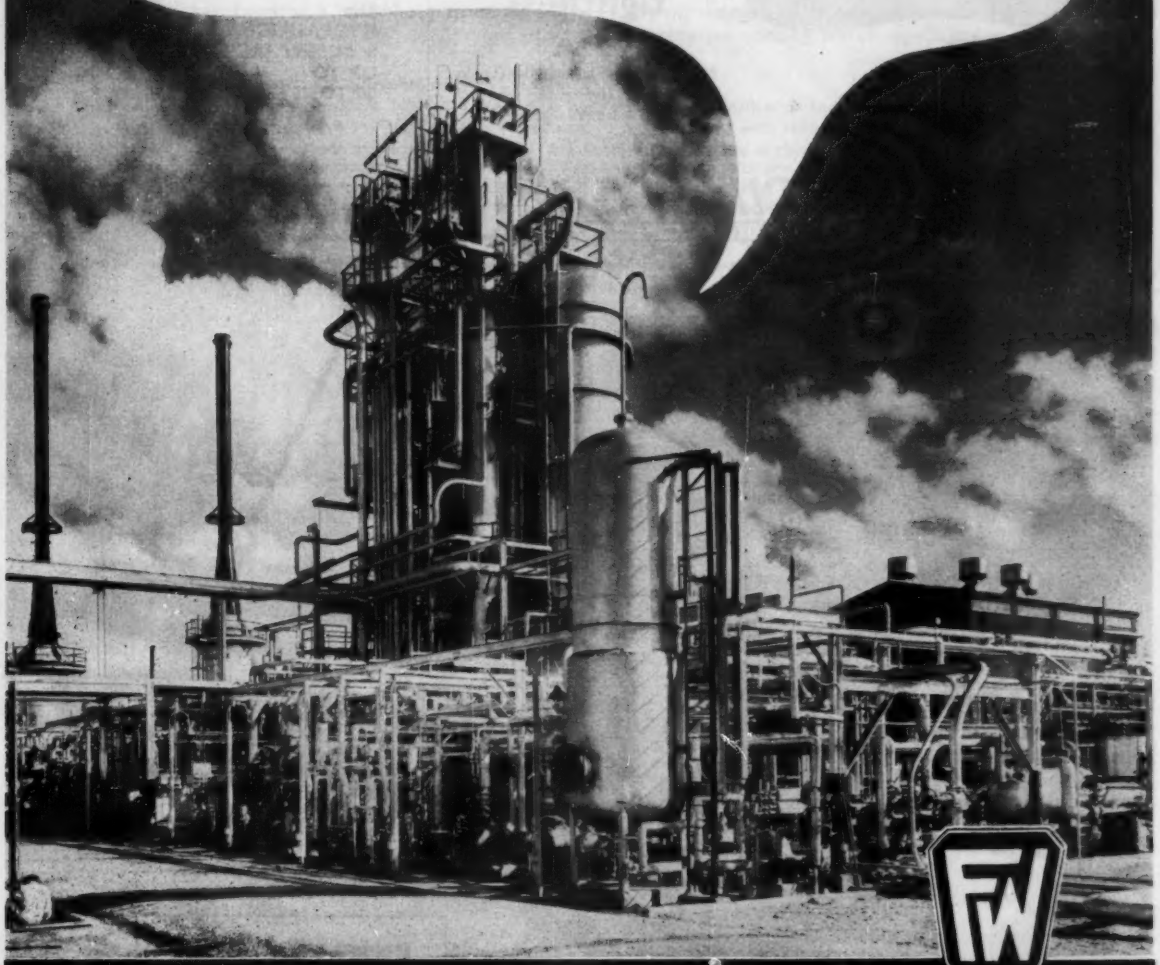
Phenol Treating Plant

Foster Wheeler have designed and built a group of units at the Esso Refinery at Fawley for the production of high grade lubricating oils. The phenol treating plant shown is one of this group which includes units for propane deasphalting, propane dewaxing and clay contacting.



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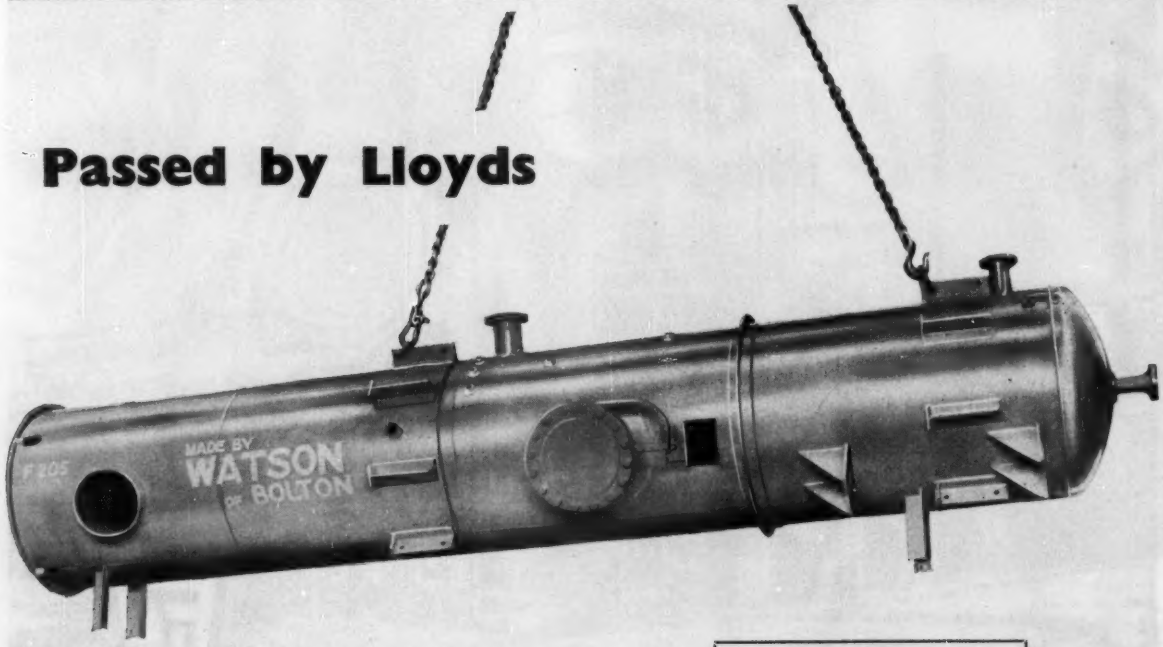

Constructed to API-ASME Code this vessel is 12 ft. long and 4 ft. in diameter. Design pressure was 100 lb. p.s.i.g. at 50° F. and the vessel was hydraulically tested to 255 p.s.i.g.

Robert Watson are specialists in the manufacture of electrically welded pipes, pressure vessels, columns, drums and tanks and will gladly advise on any problem at the design stage.

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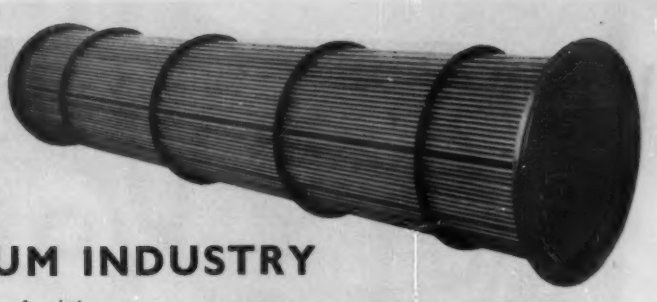
"Yorkshire" TUBES



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The Yorkshire Copper Works Ltd. are makers of solid drawn tubes in "Yorcalbro" (aluminium–brass), Admiralty Mixture Brass, 70/30 Brass, "Yorcoron", "Yorcunic", "Yorcunife" and 70/30 Cupro-Nickel, Copper, "Yorcalnic" (aluminium–bronze) and Tin Bronzes. They are also makers of Bi-metallic (Duplex) tubes and specialise in the manufacture of Heat Exchanger and Condenser Tubes. They are sole makers of "Yorkshire" Capillary Fittings.

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Bi-metallic or Duplex tubes are frequently used to overcome corrosion problems where no single alloy can provide adequate resistance to corrosion by the media in contact with the inside and outside surfaces of the tubes. "Yorkshire" Bi-metallic tubes are manufactured in combinations of steel and non-ferrous alloys, e.g. steel lined or shirted with "Yorcalbro", and in combinations of non-ferrous alloys.

"YORCALBRO"** (Aluminium–Brass) **TUBES FOR HEAT EXCHANGE EQUIPMENT

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(2) Like other "Yorkshire" alloys, it is immune from attack by dezincification and season cracking.
(3) It renders possible the much longer "on stream" runs obtainable with refinery plant today.
(4) High water speeds are permissible with "Yorcalbro" tubes because of their resistance to corrosion–erosion, and initial heat transfer is better maintained with this alloy than with any other alloy.
(5) Although the cost of "Yorcalbro" is about 6 per cent higher than that of ordinary brass tubes, this is offset by its longer life and trouble-free service, resulting in reduced maintenance charges.

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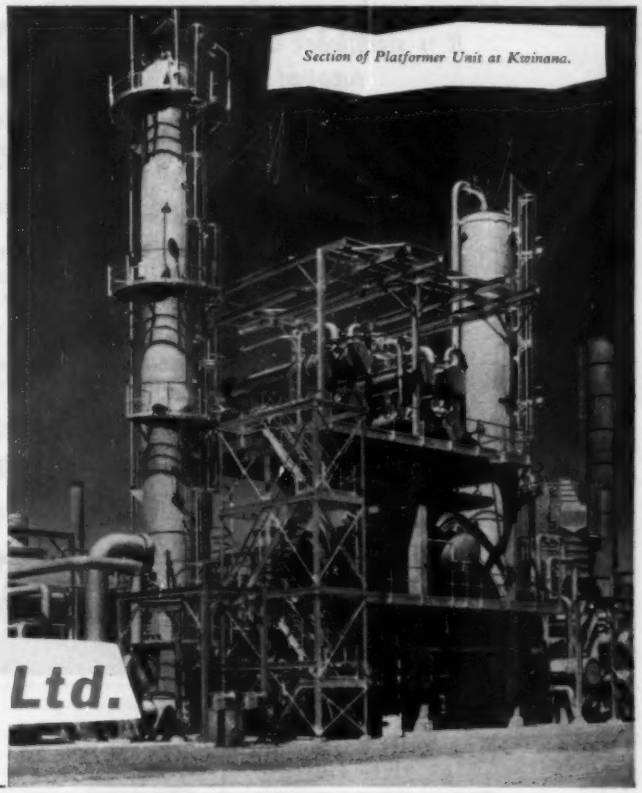
Kwinana Refinery



Section of Platformer Unit at Kwinana.

Glitsch *"Truss-Type"* * bubble trays were specified for the British Petroleum Refinery at Kwinana, Western Australia. The trays we supplied for the Platformer Unit (see illustration) were in 12/14 chrome, mild steel and Monel material.

* Covered by British patents.

Metal Propellers Ltd.

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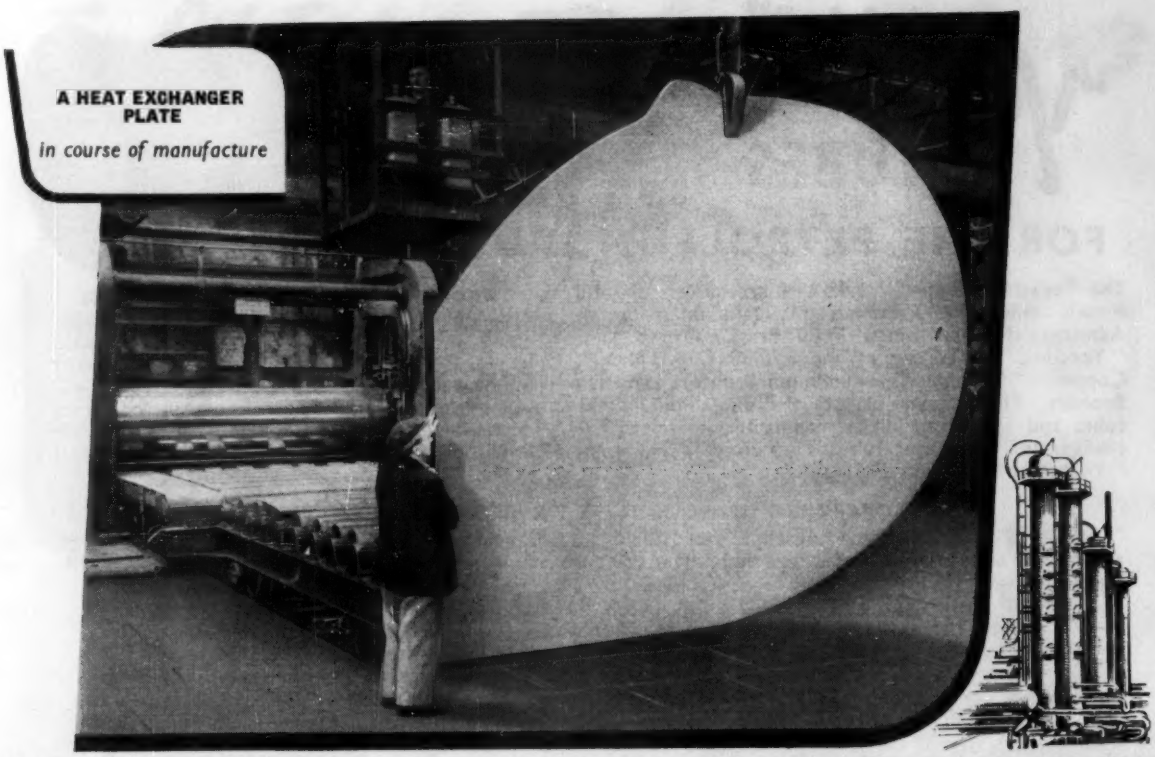

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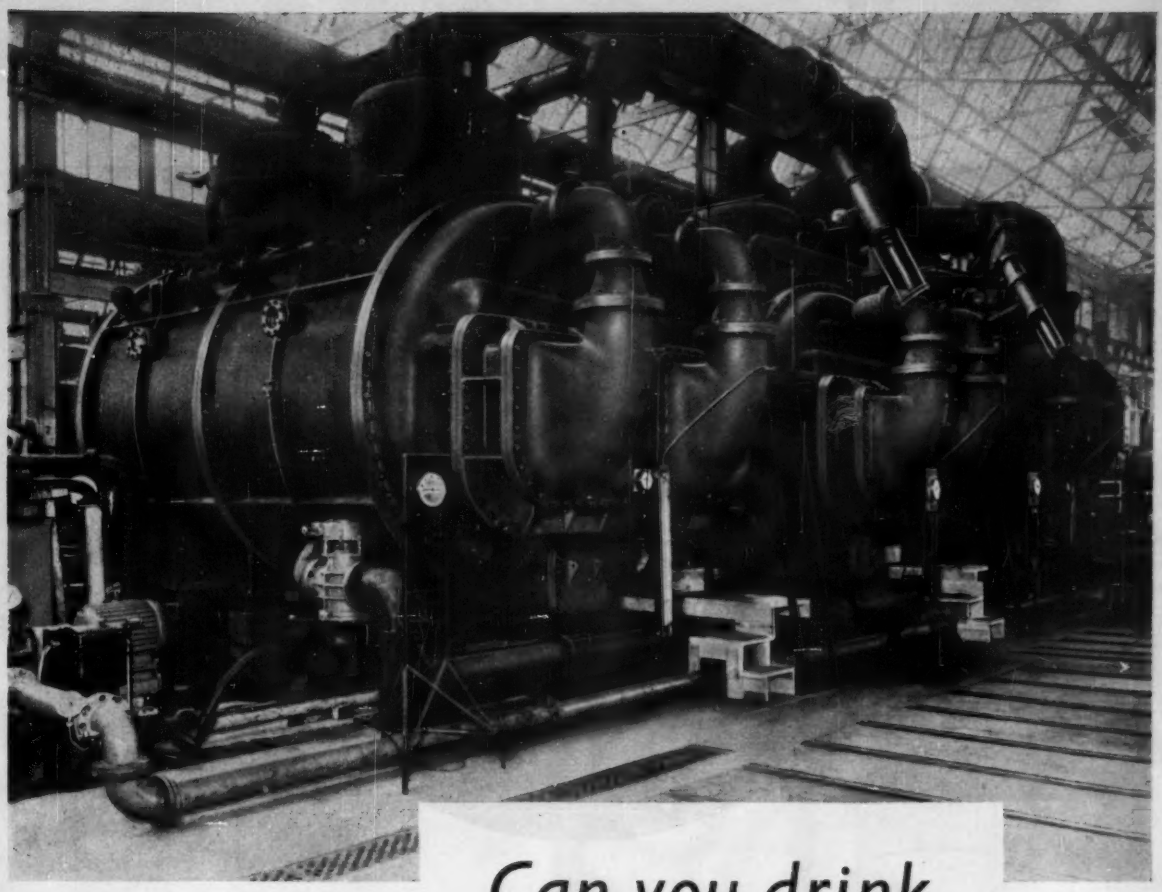

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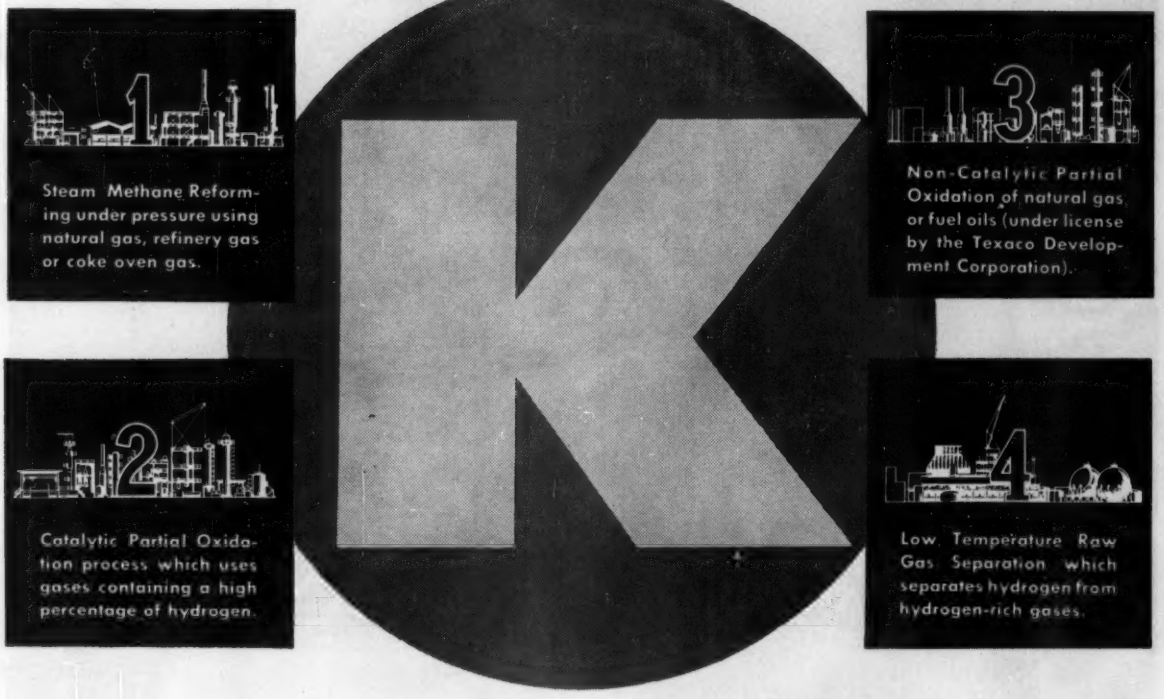
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Steam Methane Reforming under pressure using natural gas, refinery gas or coke oven gas.
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Non-Catalytic Partial Oxidation of natural gas or fuel oils (under license by the Texaco Development Corporation).
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Catalytic Partial Oxidation process which uses gases containing a high percentage of hydrogen.
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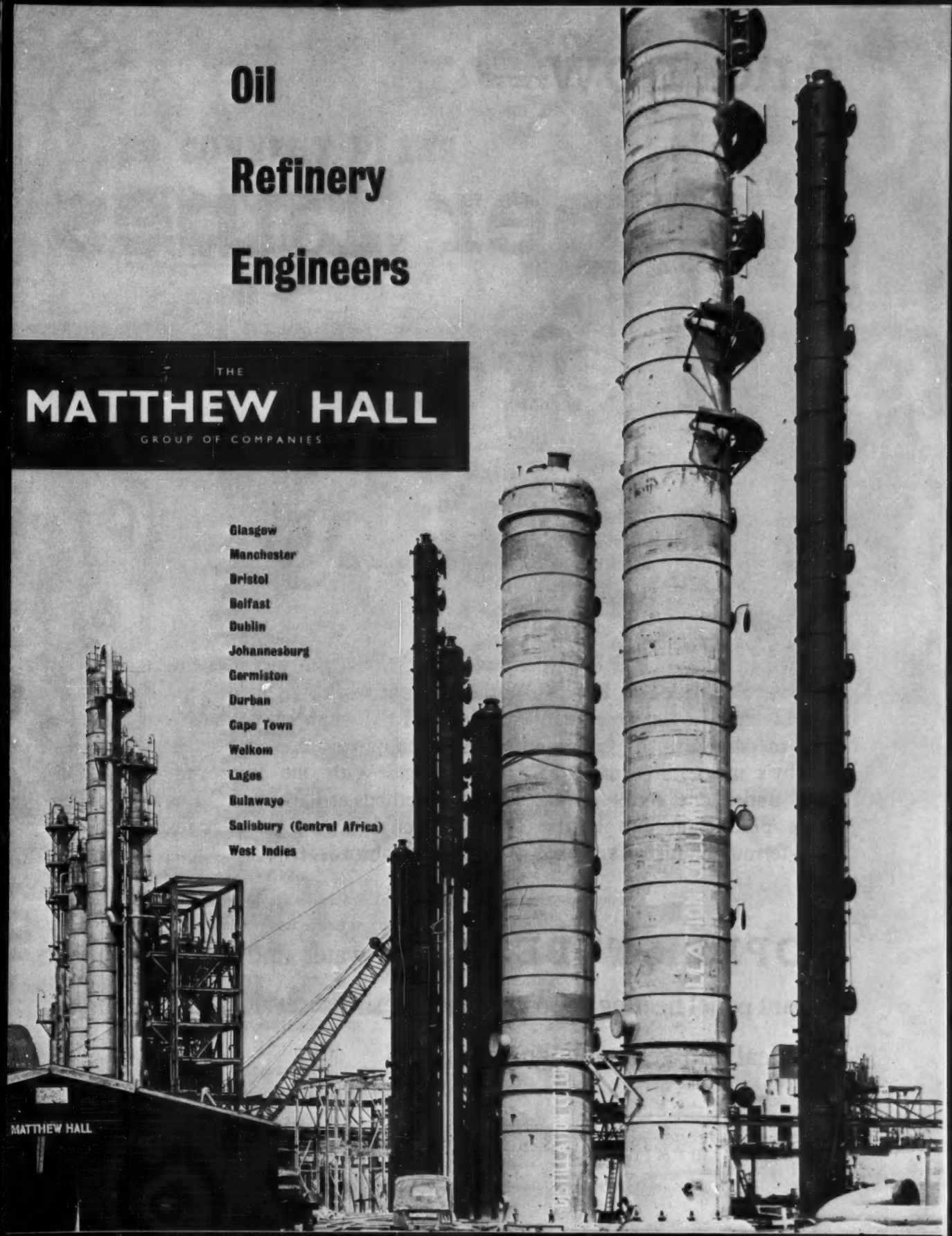

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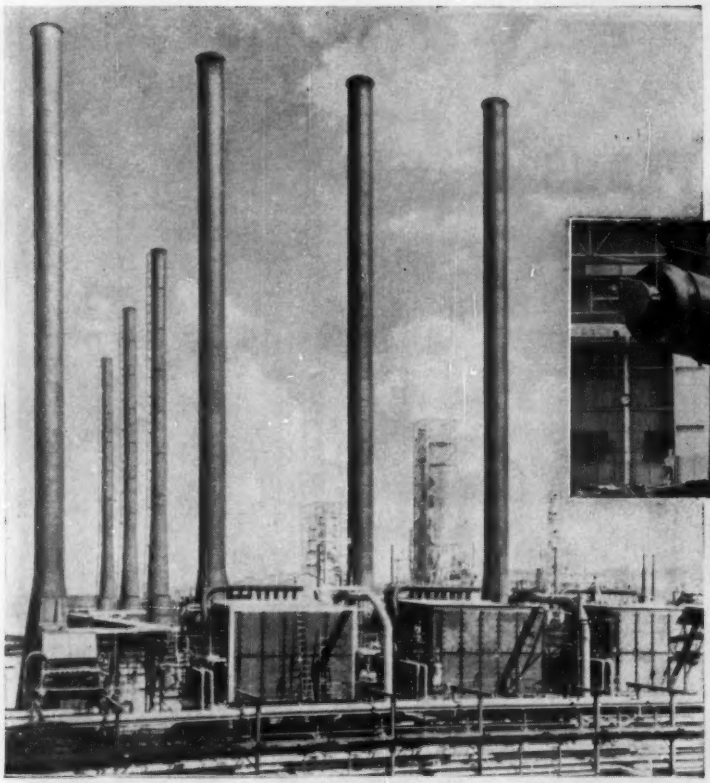
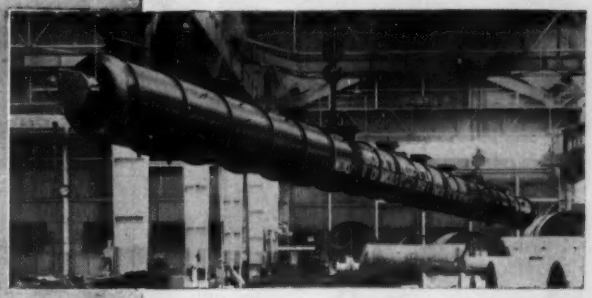


(left)
Babcock oil-fired boiler plant at Burmah-Shell refinery, Trombay, India.



(above)
Babcock fusion-welded treating tower for a Scottish chemical plant.

BABCOCK

Equipment for the Oil and Chemical Industries

THE complete outdoor boiler installation (above) at the Burmah-Shell Refinery, Trombay, with its oil-fired boiler plant, separately-fired superheater and steel, self-supporting chimneys, all manufactured and installed by Babcock & Wilcox; and the 110′ long x 4′ 6″ i.d. topping tower (right) — one of a number of Babcock fusion-welded pressure vessels for a chemical plant in Scotland, are an indication of the wide range and world-wide service offered by BABCOCK to the oil and chemical industries. This service includes the design, manufacture and installation of all kinds of water-tube boilers, oil-fired "packaged" boilers, and waste-heat boilers, heat-exchangers and separately-fired superheaters for very high temperatures; also jib and travelling cranes, conveyors and other mechanical handling plant.

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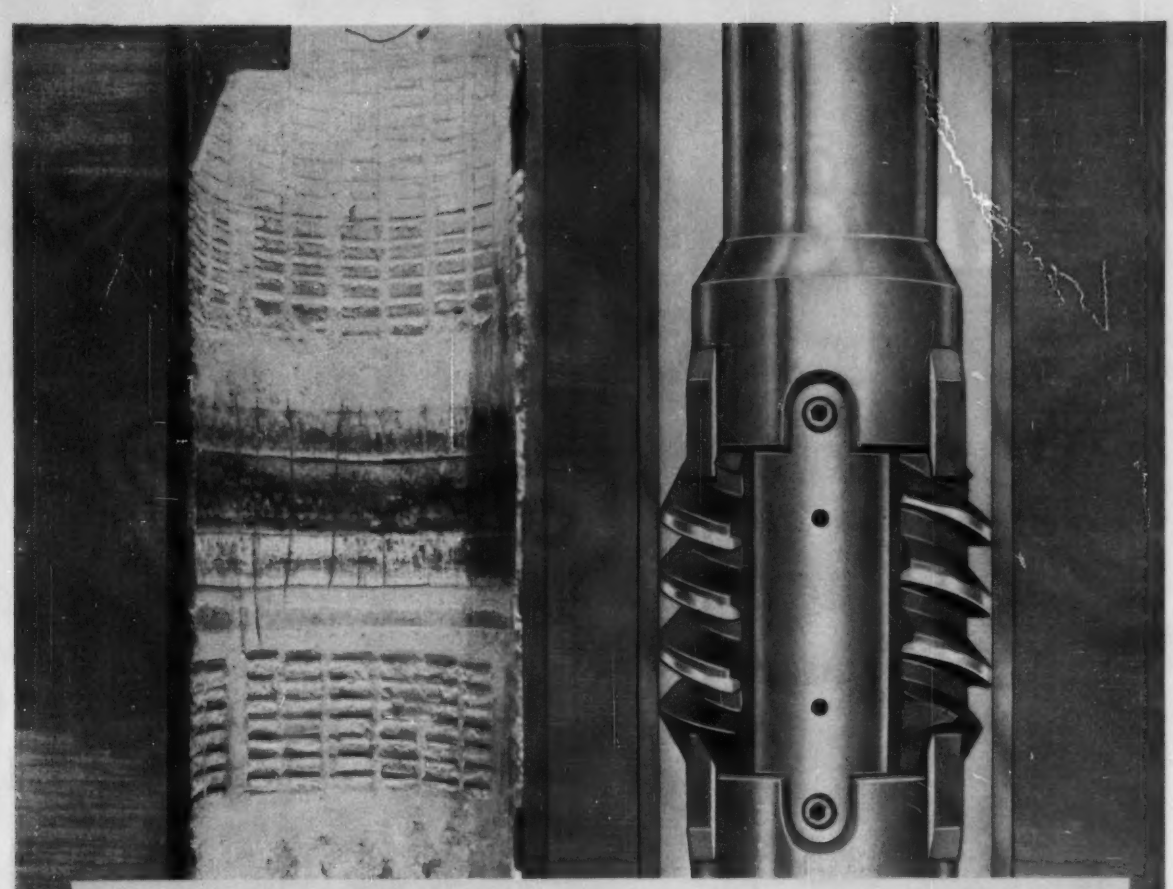

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This is just another way of asking "CAN YOU AFFORD THE EXPENSE OF DOWN-HOLE EQUIPMENT FAILURES?" The unretouched photograph at the above left provides visual proof of how casing neglect can cause even the best pack-off tool to fail.

In this case the pack-off tool set and packed-off perfectly—but the casing ID failed to do its part. Notice the cracks in the cement sheath in the area where the Packing Element was packed-off. *These cracks allowed the fluid under pressure to by-pass, even though the tool was securely set and completely packed-off.*

The Baker Roto-Vert Casing Scraper, which can be run on tubing, drill pipe or wire line, completely removes cement sheath and other obstructions such as perforation burrs and imbedded bullets—prepares the casing ID for subsequent work with pack-off tools. Remember, the condition of your casing ID is just as important to the successful operation of pack-off tools as the condition of a valve seat is to the operation of a valve.

Why take chances with so much at stake? The safe, positive, economical way to eliminate failures, such as the one illustrated above, is to make the running of a Baker Model "C" Roto-Vert Casing Scraper a part of your standard operating procedure.

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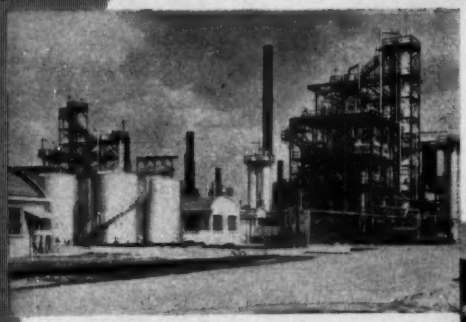
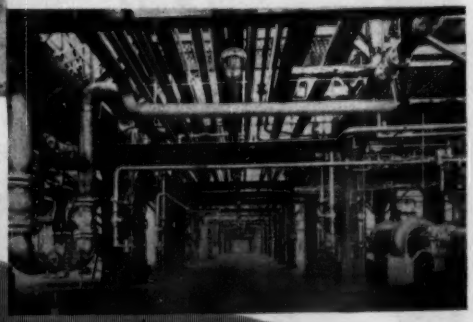


General view of crude, visbreaking, desulphurising, recovery and stabilisation units.

Graphic type panels are installed on both sides of control room with operator desk panels in centre. Crude and visbreaker unit panel is illustrated.

General view of Refinery with Mantova in background.



Over-head steam, water, oil and gas lines substantially supported and conveniently located for distribution between the units.

The Refinery was designed by the Koch Engineering Company, Wichita, Kansas, U.S.A.

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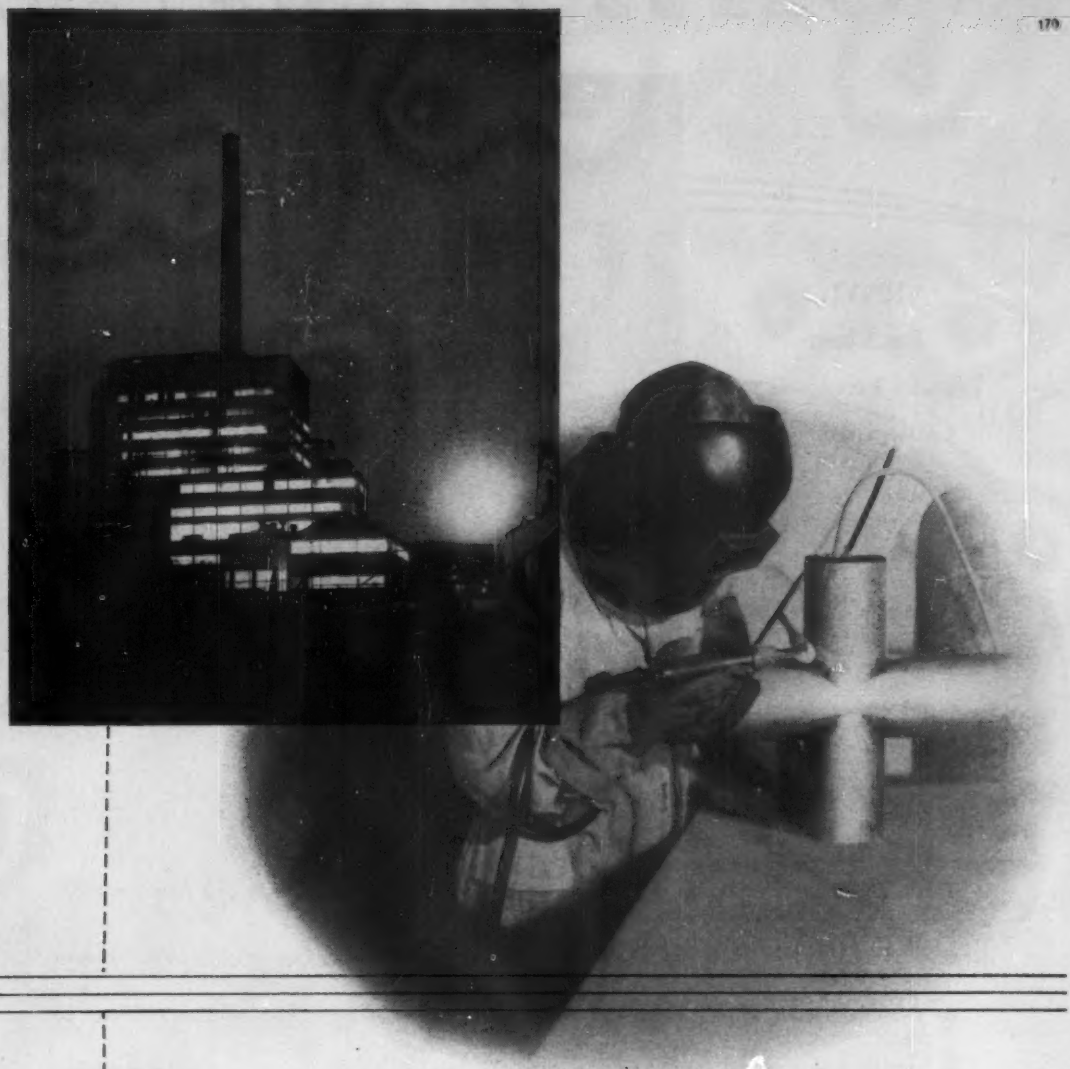

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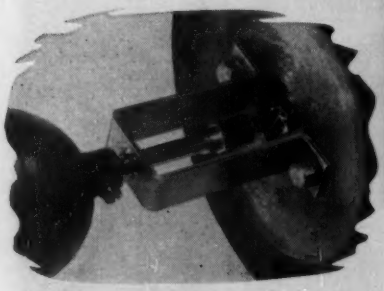

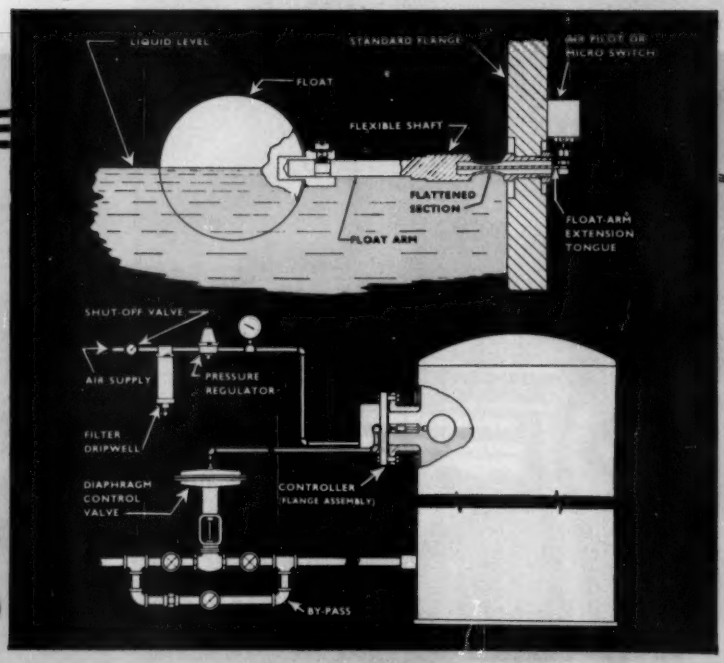

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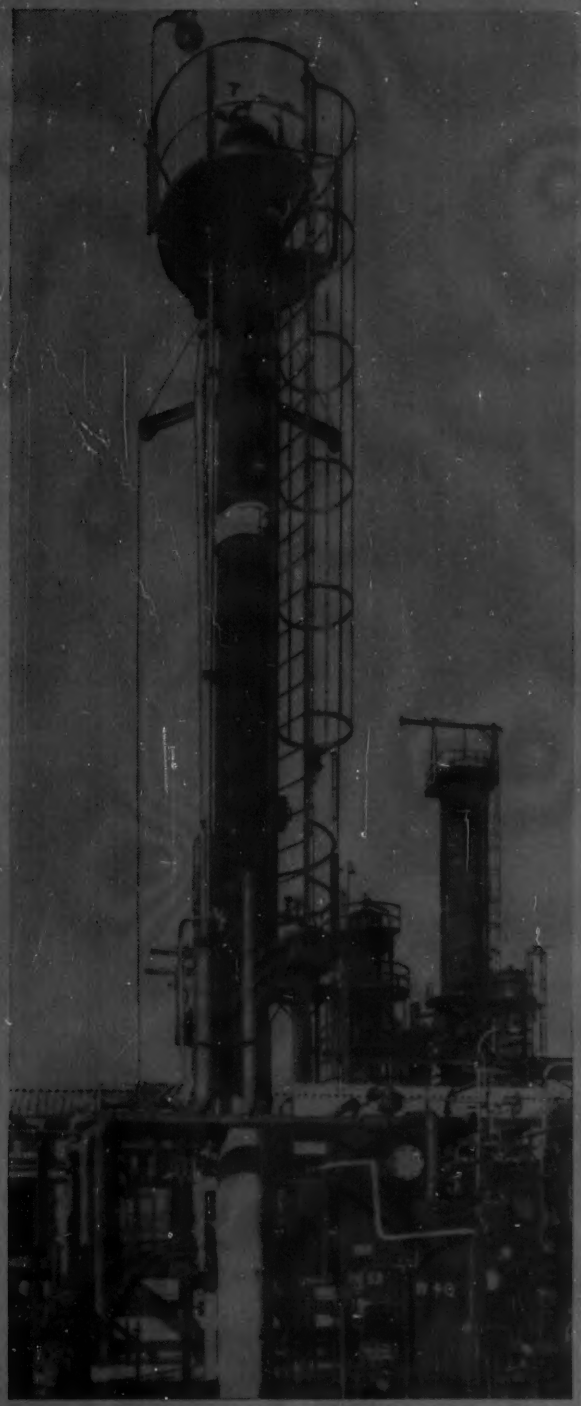

Caustic Stripper Column at Lobitos Oil Refinery, Ellesmere Port, manufactured by Metal Propellers Ltd. Column, pipe lines, tees and heat exchanger parts in Monel.

Caustic Corrosion?

No problem with MONEL

Gasoline distillates often contain small amounts of mercaptans, compounds analogous to alcohols but containing sulphur in place of oxygen. Mercaptans are malodorous, have adverse effects on octane ratings, and are corrosive in certain conditions.

In the Unisol Process, developed by Universal Oil Products Company, mercaptans are removed by contacting the distillate with methanol and caustic soda in a liquid-liquid counter-current extraction system. Treated gasoline is withdrawn from one end of the system and the mercaptan-containing caustic methanol solution from the other. The caustic is recovered by stripping free of methanol and mercaptans using live steam in a Monel column packed with carbon Raschig rings. The methanol and mercaptans are obtained as overhead products in this column, both the methanol and caustic being available for further service.

The Ellesmere Port refinery of Lobitos Oilfields Ltd., has a caustic stripper of this nature made entirely of Monel plate. Pipe lines, tees and heat exchanger parts are also of Monel. Monel is resistant to caustic at temperatures and concentrations which would cause damage to steel equipment by caustic embrittlement.

Corrosion test results and service records point to the suitability of Monel, as well as nickel and Inconel for use in resisting caustic corrosion.

This instance is just one of the many where Monel is used in countering corrosion. Our publication "Monel & 'K' Monel, Properties & Applications" and detailed information on other Wiggin nickel alloys will be sent without charge, on request. Your specific problem will gladly be dealt with by our Technical Service.

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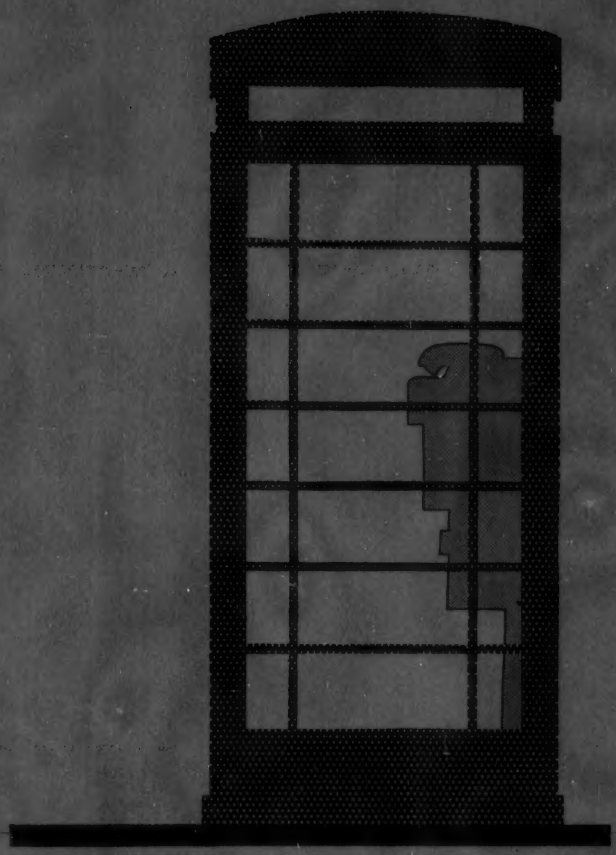

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